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FOOD:

ITS ADULTERATIONS, AND THE METHODS FOR THEIR DETECTION.

BY

ARTHUR HILL HASSALL, M.D. LOND.

Member of the Royal College of Physicians of England; Senior Physician to the Royal Free Hospital, London; Founder of and Physician to the Royal National Hospital for Consumption and Diseases of the Chest; Author of The Reports of 'The Lancet *Analytical Sanitary Commission' on Food, published under title of 'Food and its Adulterations;' of 'Adulterations Detected;' also of 'A History of The British Freshwater Algæ,' 'The Microscopic Anatomy of the Human Body,' 'The Urine in Health and Disease,' and other works.*

ILLUSTRATED BY UPWARDS OF 200 WOOD ENGRAVINGS.

LONDON:
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1876.

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PREFACE.

Eighteen Years have elapsed since the Author's work entitled 'Adulterations Detected in Food and Medicine' was published.

Since that date the knowledge of the subject of the Adulteration of Food has greatly extended, and the methods for its detection have become much more definite and precise.

During the whole of the intervening period the author has himself been unceasingly occupied with the subject, having made numberless analyses, and having been constantly engaged in special investigations relative to the adulteration of certain articles of food.

Although in the present work the Author has followed somewhat the method adopted in his previous books on the same subject, yet the volume now published contains a large amount of additional matter, several of the subjects being treated of for the first time, as the articles on Food, its Functions and Quantity; The Preservation of Food; Unwholesome and Diseased Meat; Water; Aërated Waters; Lime and Lemon Juices; Cider and Perry; Tinned Vegetables; and the Utensils employed in the Preparation and Storage of Food; while nearly the whole of the articles which are not entirely new have been much extended or entirely re-written. The Author has therefore deemed it best to bring the book out under a new title, and not as a fresh edition of his former work, 'Adulterations Detected.'

He now desires to record the obligations he is under to his assistant, Mr. Otto Hehner, who has ably and cheerfully rendered him much valuable aid, more particularly in the purely chemical portions of the work.

St. Catherine's House, Ventnor:
November 1875.

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FOOD:

ITS ADULTERATIONS
AND
THE METHODS OF THEIR DETECTION.

CHAPTER I.

ON FOOD, ITS FUNCTIONS AND QUANTITY.

It will facilitate the comprehension of much that is to follow, and enable us to answer questions which will be often put to us as to the quality, genuineness, wholesomeness, and quantity of the various kinds of food consumed, if we first bestow a few observations upon the functions performed by the several classes and kinds of food, and the amounts necessary to the growth, sustenance, and maintenance of the body in a state of health.

The bodies of men and animals are built up of several substances; some of these, from the fact of their containing nitrogen, are called *nitrogenous*; others, being destitute of that principle, are termed *non-nitrogenous*, or *carbonaceous*, *mineral* constituents, and *water*.

The principal nitrogenous substances of the animal body are fibrin, found in the blood and muscles; albumen and globulin, abounding in the blood; gelatine, in the bones, tendons, and ligaments; and casein, in milk; while the chief non-nitrogenous constituent is fat; they are identical in their ultimate composition, and contain carbon, hydrogen, nitrogen, oxygen, and sulphur, in the following proportions:—

Carbon	53·5
Hydrogen	7·0
Nitrogen	15·8
Oxygen	22·1
Sulphur	1·6
	100·0

Now, the vegetable has a composition resembling, in the main, that of the animal, it containing analogous nitrogenous substances, though usually in smaller amounts; while the fat is represented chiefly by sugar and starch, though in some exceptional cases fat or oil is met with, as in the seeds of various plants. All the nitrogenous substances entering into the composition of the human and other animal bodies are derived, either directly or indirectly, from the vegetable kingdom, the vegetable being constructive and the animal destructive.

The nitrogenous elements are capable, under some circumstances, of furnishing both fat and sugar; thus, there is evidence to show that the fatty matter of milk and the sugar of diabetes are thence derived, at least to some extent. Again, starch and sugar are sometimes transformed into fat, but the greater part of the fat of the body is derived from that contained in the food.

Notwithstanding this partial and occasional formation of fat from the nitrogenous, starchy, and saccharine elements of the food, each separate class is needed to sustain the body in a state of health. Thus, perfect health cannot be maintained for any length of time on nitrogenous food alone, even with water and the mineral constituents; and although it may be supported for a longer period on such food combined with fat, yet, for perfect health, the albuminates, fat, and the carbo-hydrates, as sugar and starch, are all necessary, though how the latter act in nutrition is not yet fully understood, since they do not enter into the composition of the tissues like the others. Further, it should be clearly understood that excess of lean meat increases the oxidation of the fat, thus tending to the reduction of obesity; excess of the carbo-hydrates acts in the same way.

Now, these several nitrogenous and non-nitrogenous constituents of the food are constantly undergoing change and destruction in ministering to the several necessities of the living animal organization, as the growth, sustenance, and waste of the body, its heat, electricity, and muscular force; and hence the necessity for a frequent supply of food. The various constituents of the food, having served the several purposes in the animal economy which have been already noticed, are eliminated from the system, the nitrogenous chiefly as *urea*, *uric* and *hippuric acids*, *creatine* and *creatinine*, and the non-nitrogenous in the forms of *carbonic acid* and *water*.

While starch and sugar only want as much oxygen for complete combustion as is required to combine with their carbon, fat needs a larger proportion, for it contains an excess of hydrogen, which consumes a proportionate amount of oxygen to form water. By the combustion of fat, therefore, more heat—2·4 times as much—is developed, than by an equal quantity of starch or sugar.

Now, the process of respiration is merely an act of combustion; the air carried to the lungs by inspiration is there deprived of much of its oxygen, while, in place of this gas, the expired air contains a proportionate quantity of carbonic acid, which is derived from the food introduced into the blood, and especially from its non-nitrogenous constituents, which may be termed 'heat producers,' for by their oxidation the heat of the body is chiefly obtained.

With respect to the fatty substances which enter into the composition of our food, we would remark that they are not merely heat producers, but that they play a very important part in the process of digestion, not only increasing and accelerating greatly the digestibility of nitrogenous articles of food, but also aiding in the formation of bile.

Again, the starch is converted in the system into glucose, which is carried by the blood to the lungs, where it is split up into carbonic acid and water, as already described. Another product of the oxidation of starch and sugar is *lactic acid*, an important constituent of the gastric juice.

Starch, sugar, and fat have the following formulæ and percentage composition:—

	Cane-sugar, $C_{12}H_{22}O_{11}$	Glucose, $C_6H_{12}O_6$	Starch, $C_6H_{10}O_5$	Fat (stearine), $C_{57}H_{110}O_6$
Carbon . . .	42·10	40·00	44·44	76·85
Hydrogen . . .	6·44	6·67	6·18	12·36
Oxygen . . .	51·46	53·33	49·38	10·79
	100·00	100·00	100·00	100·00

The *mineral* constituents of the body are not less necessary than the albuminates, fat, and the carbo-hydrates, and equally require to be renewed in the food consumed. Thus, sulphur and phosphorus are constantly present, combined chiefly with the albuminates. Phosphate of lime is found principally in the bones, teeth, and growing cells and tissues; phosphate of potash in the tissues, cells, and blood—the latter fluid is particularly rich in basic phosphate of potash, which forms by far the largest portion of its mineral constituents; chloride of sodium in the liquids, iron in the blood, and, lastly, carbonic, lactic, tartaric, acetic, and some other acids, which are converted in the system into carbonic acid, are requisite to maintain the alkalinity of the body, the absence of which gives rise to scurvy.

The function of chloride of sodium, or common salt, is but ill understood. It has been asserted that it is necessary for the assimilation of the food, but this seems not to be the case. Salt, in fact, is considered by some to be quite a superfluous addition to most of our articles of food, and nothing more than a condiment. It does not enter into the composition of any of the tissues, but is thrown out of the system in the excretions; and it has been repeatedly shown that some tribes of natives of Africa do not know the use of salt at all, and consider it a luxury and delicacy.

Iron is a most important constituent of the blood; the colouring matter of the red corpuscles contains it in chemical combination. It is said to assist in the oxygenation of the blood.

Again, the imbibition of a large quantity of water daily is likewise a necessity, in order to endow many of the constituents of the food—especially the albuminates—with certain physical properties, to render them plastic, soluble, or the more readily reducible to a state of solution; thus aiding absorption, nutrition, and elimination.

To sum up then, there is between the composition of the body and the food consumed, whether animal or vegetable, the closest possible resemblance.

Having thus enumerated the various kinds of food required to sustain the body in health, we have to consider the *quantities* needed. It will be obvious from what has already been advanced, that the quantities will vary, being dependent upon age, weight, muscular exertion, climate, &c.; but it has been determined by numerous independent inquiries, that the food daily consumed by an adult man of average weight—140 lb.—and in moderate work, should contain about the following quantities of the several classes of food, the figures given being those of Moleschott, quoted by Parkes in his admirable work on 'Practical Hygiene,' and which figures should be generally adopted, in order to save the multiplication of sums and calculations:—

Dry food.	Ounces.	Nitrogen grains.	Carbon grains.
Albuminous substances	4·587	317·0	1073·6
Fatty substances	2·964	None	1024·4
Carbo-hydrates	14·257	None	2769·4
Salts	1·058	...	...
	22·866		

One ounce of dry albuminate contains 69 grains of nitrogen and 234 of carbon; 1 ounce of dry fat, 336·0 grains of carbon, and the same weight of either of the carbo-hydrates, starch or sugar, 194·2 grains; or 100 grains of albuminates contain 15·8 of nitrogen and 53·5 of carbon; fat, 76·8 grains of carbon, and starch and sugar 44·4 grains.

But water to the extent of between 50 and 60 per cent. is contained in the food consumed, raising the amount to about 40 ounces.

Now, nearly the whole of the nitrogen and carbon contained in the chief articles of our food may be thus divided and distributed:—

Lean raw meat	16 oz., less one-fifth bone, 14·4 = cooked, about 8 oz.
Fat of meat	½ ounce.
Egg	2 "
Cheese	1 "
Butter	1 "
Bread	18 "
Potatoes	16 "
Other vegetables	8 "
Milk	2 "
Sugar	¾ "

Having thus arrived approximately at the quality and quantity of the several kinds of food required by an adult man of average size and weight, and in moderate work, it next becomes important to explain how each person may calculate for himself, and so ascertain the nutritive quality of his own, or any other, dietary. This important object may be accomplished by the help of the following table, taken, with one exception, from the work of Dr. Parkes, before quoted:—

Table for calculating Diets.

	Water.	Albuminates.	Fats.	Carbo-hydrates.	Salt.
Lean raw meat, bone-free	75	15	8·4	...	1·6
Fattened meat (Gilbert and Lawes)	63	14	19	...	3.7
Roast meats (no dripping being lost), Ranke. (Boiled assumed to be the same)	54	27·6	15·45	...	2·95
Bread	40	8	1·5	49·2	1·3
Flour	15	11	2	70·3	1·7
Biscuit	8	15·6	1·3	73·4	1·7
Rice	10	5	·8	83·2	·5
Oatmeal (Von Bibra)	12	16	6·8	63·2	2
Oatmeal (Letheby)	15	12·6	5·6	63	3
Maize (Poggiale)	13·5	10	6·7	64·5	1·4
Peas, dry	15	22	2	53	2·4
Potatoes	74	1·5	·1	23·4	1
Carrots (all cellulose excluded)	85	·6	·25	8·4	·7
Cabbage	91	·2	·5	5·8	·7
Butter	8·8	2·7	85	...	3·5
Eggs, less 10 per cent. for shell	73·5	13·5	11·6	...	1
Cheese	36·8	33·5	24·3	...	5·4
Milk (specific gravity 1030)	86·7	4	3·7	5	·6
Milk (specific gravity 1026)	90	3	2·5	3·9	·5
Sugar	3	...	...	96·5	·5

The use of the above table is exceedingly simple. Thus, the quantity by weight of any of the articles enumerated being known, the amounts of the albuminates, fats, and carbo-hydrates are easily calculated by a simple rule-of-three sum. Thus, supposing the allowance is 12 oz. of meat, one-fifth must be deducted for bone; the water in remaining 9·6 oz. will be ascertained as follows: $\frac{75 \times 9\cdot6}{100} = 7\cdot2$; and so on for the other constituents.

A few words in conclusion may be bestowed on the relative digestibility of different articles of food.

It appears from Dr. Beaumont's experiments on Alexis St. Martin that 'animal food is digested sooner than farinaceous, and, possibly, meat might therefore replace more quickly the wasted nitrogenous tissue than bread or peas; and it may be true, as asserted, that the change of tissue is more quick in meat-eaters, who require, therefore, more frequent supplies of food.'

'Rice, tripe, whipped eggs, sago, tapioca, barley, boiled milk, raw eggs, lamb, parsnips, mashed and baked potatoes, and fricasseed chicken, are the most easily digested substances in the order here given, the rice disappearing from the stomach in one hour, and the fricasseed chicken in 2¾ hours. Beef, pork, mutton, oysters, butter, bread, veal, boiled and roast fowls are rather less digestible, roast beef disappearing from the stomach in three hours, and roast fowl in four hours. Salt beef and pork disappeared in 4¼ hours.'—*Parkes.*

The admixture of the different classes of food aids digestibility, and fat taken with meat helps the digestion of the meat.

'According to the best writers on diet, it is not enough to give the proximate dietetic substances in proper amount. Variety must be introduced into the food, and different substances of the same class must be alternately employed. It may appear singular that this should be necessary; and certainly many men and most animals have perfect health on a very uniform diet. Yet there appears no doubt of the good effect of variety, and its action is probably on primary digestion. Sameness cloys; and with variety more food is taken, and a larger amount of nutriment is introduced. It is impossible, with rations, to introduce any great variety of food; but the same object appears to be secured by having a variety of cooking.'—*Parkes.*

CHAPTER II.

ON THE PRESERVATION OF FOOD.

It will be desirable before entering on the question of the adulteration of food to devote a short chapter to the subject of the various methods employed for its preservation. The methods resorted to are exceedingly numerous, and many of them have been patented on account of their supposed commercial importance, but they may be all referred to the following heads :—to preservation by *temperature,* including an *elevation* of temperature, resulting in more or less complete cooking, and a *reduction* of temperature, as by freezing; by the *exclusion of air,* as when animal and vegetable substances are enclosed in hermetically-sealed tins; by *coating* the surface, as by paraffin, or when an artificial coating is formed by the coagulation of the albumen by plunging it into hot water; by *immersing* or *mixing* the substances to be preserved with a material which acts in the preservation mainly by the exclusion of air, as syrup or sugar; by *compression,* which serves to exclude the air partially, as also to remove superfluous moisture; by the *extraction of certain principles* of meat by means of water, and the subsequent inspissation of the extract; by the use of various *antiseptic substances,* as alcohol, acetic acid, salt, saltpetre, alum, creosote, and charcoal; by the employment of *certain acids and gases,* as sulphurous acid and the sulphites, especially sulphite of soda, which retard decomposition by combining with the oxygen of the air, which, in spite of all precautions, cannot be altogether excluded from the preserved material; by *carbonic acid,* which acts by exclusion of the air, and the substitution of an atmosphere unfavourable to decomposition.

In many cases more than one of the above agencies are at work in the preservation of the food, as for example in tinned meats, in which not only is the air excluded, but the albumen of the meat is coagulated by cooking; in preserved milk, in which the greater part of the water is removed by evaporation, the albumen coagulated by the heat employed, and the air partially excluded by the addition of powdered sugar.

We will now give some brief examples illustrative of each of the methods of preservation above referred to.

Elevation of temperature.—Heat is employed for the double purpose of partially cooking the materials to be preserved, whereby the albuminous matters are coagulated, and of assisting in driving out the air; as in the case of all jams and preserves, bottled fruits and vegetables, all tinned meats and vegetables; and, lastly, as in the coagulation of the albumen near the surface of a joint of meat.

By reduction of temperature.—This principle acts by retarding decomposition, and the development and growth of minute organisms, and, when the substance itself is actually frozen, also by the exclusion of air. Its effect is very great, as is known to every householder, and is shown by the remarkable cases which have been recorded of the preservation of human and animal bodies, and of meat, through a long series of years in regions of perpetual frost. Every one is acquainted with the fact that perfectly well-preserved bodies of the Mammoth, a huge species of elephant, which died out ages ago, have been found imbedded in the ice of Siberia.

In 1861 three human bodies were discovered under the Glacière des Bossons, near Chamounix, in a perfect state of preservation. Forty-one years ago, in 1820, these men had lost their lives by an avalanche.

In 1824, the Arctic exploring ship 'Fury' was wrecked in the Prince Regent's Inlet, and its stores were landed and placed upon the beach. After eight years' exposure, Sir John Ross found them in a perfect state of preservation, and after a further lapse of sixteen years, H.M.S. 'Investigator' found them in the same condition.

Our ordinary ice-safes are constructed on this principle, and one of the latest proposals is to import meat on a large scale in specially-constructed ice compartments or safes.

By exclusion of the air.—The most complete example of the employment of this principle is furnished by the tinning of vegetable and animal substances, an operation which is thus conducted:—The meat or vegetable is put, with the addition of some water, into a suitable tin; the lid, having a small hole at the top, is now fastened down. It is heated to boiling, and as soon as the steam has driven out all the air, the hole is closed by solder. In this case, the tin contains an atmosphere of steam. In other methods, the tin is filled with an inert gas, such as carbonic acid, or nitrogen. Other examples of more or less complete exclusion of the air have already been given.

By the employment of sugar.—This substance is used extensively in the preservation of fruits, as Normandy pippins, pears, jams, preserves, vegetable jellies, fruit syrups, essences and acids, bottled and crystallised fruits, and condensed milk.

By compression.—This principle has been in operation for a great many years, combined in some instances with partial drying, with great success in the preservation of vegetable substances. An illustration of this method is afforded by the various vegetables preserved by the patent of Masson.

By removal of water. — This principle has also been resorted to with considerable effect either by itself or in conjunction with the employment of a certain temperature. It was applied especially by the author for the preservation of an article which he prepared termed 'Flour of meat,' in which the lean portions of the meat were dried at a temperature below that at which albumen coagulates, and afterwards reduced, by grinding and passing through sieves, to a powder as fine as that of wheat flour. This method has also been used very successfully under Edwards' Patent for the preservation of the Potato. This vegetable contains 75 per cent. of water, the greater part of which being removed by drying at a low heat, the potato is found to keep well, it reacquiring the water it had lost in the process of cooking.

Condensed milk also owes its preservation in part to the removal of the water.

By extraction with water and subsequent inspissation.—In this manner Liebig's Extract of Meat is prepared; this extract contains neither gelatine nor albumen, and its mode of preparation is as follows:—the flesh is extracted with cold water, the solution is boiled, and thus freed from albumen; when clear it is evaporated to the consistency of a syrup.

The concentrated beef-teas are also prepared by extraction with water; one of the best of these is that made by Brand; the beef is in this case extracted with boiling water.

By alcohol.—The preservative powers of alcohol in a very great measure also depend upon the desiccation of the materials to be preserved, alcohol having a very great affinity for water. It moreover destroys any organic germs and organisms which may be present or prevents their developement and growth. In consequence of the cost of this substance, it is but little employed in the preservation of articles of food; but cherries, and some other fruits, are sometimes preserved, as is well known, in whisky and brandy.

By acetic acid.—This is generally used in the form of vinegar, and it is supposed to act by its antiseptic properties. It is the principal vehicle in which the various forms of pickles are preserved, and it forms an important constituent in most sauces.

Closely allied in their action to vinegar are certain salts, such as *common salt* (chloride of sodium), *saltpetre* (nitrate of potash), and *alum* (sulphate of alumina and potash), all being powerful antiseptics. The salting of meat, fish, and butter, and the preservation of meat by the addition of a little saltpetre, offer well-known illustrations of the use of these substances.

By creosote.—The smoking of meat over wood fires, and its keeping qualities when thus prepared, depend to a great extent upon desiccation, but an important part is played by an interesting constituent of the smoke—namely, creosote. This substance prevents the growth of organisms and consequent putrefaction even when present in very minute quantity. It is closely allied and perhaps identical, chemically and in its mode of action, with carbolic acid, the most powerful of all known disinfectants.

By charcoal.—This substance operates by its powerful absorbent and oxidising properties; these are so great that when meat is placed near to, or in contact with, vegetable charcoal, although it may be in an offensive state, it is quickly deodorised and all offensiveness removed.

By sulphurous acid, free and combined.—This acid acts by taking up the oxygen of the air, with which articles of food are more or less impregnated, and which, when in the free state, aids in the decomposition of the organic substance, the sulphurous acid being converted into sulphuric acid. This acid is usually applied in solution to meat in the raw state, and, either alone or combined with other substances, it has been made the foundation upon which several patents have been obtained.

LIST OF THE PRINCIPAL PATENTS FOR THE PRESERVATION OF FOOD.

This table has been chiefly compiled in a much abbreviated form from the chapter on the Preservation of Food contained in the work by Dr. Letheby, entitled 'Lectures on Food.'

Date.	Method and Name.	
	By drying.	
1835	Newton . .	Preservation of milk by evaporation and the addition of sugar.
1847–55	Grimwade .	
1848	Louis . . .	
1847	Davison and Symington.	Preservation of eggs, by mixing the yolks and whites with flour, rice, or other starchy substances, and drying.
1793	Donaldson .	Preservation of extract of meat after the separation of the fat, by mixing with farinaceous substances, and prepared in the form of biscuits.
1851	Robertson .	
1851	Borden . .	
	Liebig	Extractum Carnis, obtained by the action of water at a low temperature, gelatine and albumen being both excluded, and the liquid extract thickened by evaporation.
1859	Blumenthal and Chollet.	Combining meat and vegetables in the form of tablets, by drying, then pressing, and finally successive immersions in rich soup.
1864	Hassall . . .	Drying meat at a temperature below that of the coagulation of albumen, and reducing it to a powder as fine as that of wheat flour.
1780	John Graefer .	Dipping vegetables into boiling solution of salt and drying them.
1820	Vallance . . .	Drying of hops, and compressing them into a small space.
1840	Edwards . . .	Boiling, granulating and drying potatoes.
1840	Grillet . . .	Preservation of cooked and uncooked potatoes by drying.
1850	Masson . . .	Preservation of vegetables by drying and compressing them to one-seventh of their original bulk.

List of the principal Patents for the Preservation of Food—cont.

Date.	Method and Name.	
	By drying.	
1874	Goundry . .	Compression of tea into tablets by means of hydraulic power. In this state it somewhat resembles the 'brick-tea' of the Tartars, but in this case the leaves are held together by means of sheep's or bullock's blood.
	Exclusion of air.	
	1	
1807	Francis Plowden	Preserving butcher's meat, animal and other comestible substances, by encrusting them with essence or extract of meat, and filling the interstices with the same.
1817	Granholm . .	By covering meat with hot fat or hot animal jelly.
1855	Wortley . . .	Preservation in oil, chiefly of anchovies and other fish.
1807	Saddington . .	Preservation of fruits without sugar. The fruit is put into bottles, heated in a water-bath to 160° to 170° F. and then the bottles are filled up with boiling water and immediately corked and cemented. Thus the air is expelled and the albumen coagulated. A little alum is frequently added.
	2	
1810	Appert . . .	The food is cooked to some extent, put into strong glass vessels, corked, wired, and exposed for some time to the action of boiling water.
1847	Bekaert . . .	Preservation of milk by evaporating it to half its original bulk, and adding some carbonate of soda.
1847	De Lignac . .	Preservation of milk by evaporation to one-sixth of its bulk before boiling it.
	3	
1810	Augustus de Heine.	Exhaustion of the air from the vessel containing the food. The vessel was furnished with a valve which allowed the air to be drawn out by means of a special apparatus.
1828	Currie . . .	After exhaustion carbonic acid is admitted into the vessel. An improvement on the preceding process.
1836	Leignette . .	Surrounds the food with a solution of salt in water, lets it out through an aperture in an atmosphere of carbonic acid, which at the same time floats in to take its place.
1842	Bevan . . .	Exhaustion of the air and substitution of a solution of gelatine.
1846	Ryan	Employment of acetic acid vapour and carbonic acid gas.

List of the principal Patents for the Preservation of Food—cont.

Date.	Method and Name.	
	Exclusion of air.	
1846	Jones and Trevethick.	Exhaustion of the vessel containing the raw food in an air-tight trough of water, and admitting pure nitrogen and exhausting again. Lastly, admitting nitrogen with a little sulphurous acid, and thus any remaining trace of oxygen is removed by its combination with the acid. Articles preserved in this manner will keep for several years.
	4	
1823	Angilbert . .	The food is put with a little water into a tin case with a hole at the top. The water is made to boil actively, and the steam thus formed escaping freely by the hole, removes the air with it, the aperture being suddenly closed.
1841	Goldner and Wertheimer.	Employment of a bath of muriate of lime to obtain a quicker and more regular generation of steam. This process is now commonly employed. The substance to be preserved is soldered down in canisters, a pinhole aperture being left in the lid. It is then subjected to the action of the bath at a temperature a little above 212° F. until the contents are about two-thirds cooked, and then, while the steam is escaping freely, the aperture is closed with solder. Lastly, the canister is subjected to a temperature high enough to favour decomposition, and if it shows no sign of bulging out from the generation of putrefactive gases, it is considered that the process has been effectually carried out.
	Hogarth and Co.	Use of steam, in place of the muriate of lime bath.
1855	Nasmyth . . .	Proposed to mix a little alcohol with the water to lower the boiling point.
	McCall . . .	Recommended less boiling and the use of a little sulphate of soda to remove any remaining oxygen.
	5	
1846	Warrington . .	Obtained a patent 'for the use of common glue, gelatine, or concentrated meat gravies or thin cream of plaster of Paris, which, when set hard, was to be saturated with melted suet, wax, stearin,'&c. 'The things were then to be wrapped in waterproof cloth or covered with caoutchouc or gutta percha, or coated with a varnish of these substances, or kept submerged in glycerine, treacle, elaines, oils, or other such matter not liable to oxidation.'

List of the Principal Patents for the Preservation of Food—cont.

Date.	Method and Name.	
	Exclusion of air.	
1855	Delabarre and Bonnet.	Preservation of meat, bread, eggs, vegetables, and pastry by coating them with a varnish of rich syrup made from the bones and flesh of animals, the substance to be preserved being parboiled.
1855	Hartnell . . .	Immersion of the animal or vegetable substances in baths of gelatine and treacle, drying, re-dipping, and covering with charcoal.
1855	Brooman . . .	Coating the meat with albumen and molasses, after the meat has been partially dried, and then suspended in an atmosphere charged with sulphurous acid.
	Bouett and Douein.	Obtained provisional protection for the use of collodion, either alone or admixed with other suitable substances.
	Redwood . .	Employment of a coating first of paraffin and then of gelatine, mixed with glycerine or treacle.
1846	Palmer . . .	Preservation of melted fats by placing them in bladders or skins.
	By cold.	
1845	Lings	Employment of ice in closed chambers. It has also been proposed to preserve food by the cold produced by the rapid evaporation of ether and ammonia, and various patents have been taken out for the formation of ice on this latter principle.
	By heat.	This principle, as we have already seen, is also employed in the preservation of food, the temperature usually resorted to varying from 200° to 212° F.
	By chemical agents.	
1800	Batley . . .	Curing and preserving fish, by salting them; vegetables, as olives, may be preserved in the same manner.
1835 1847 1851	Long . . . Horsley . . Murdoch . .	Injection of meat with a solution of sulphite of soda.
1854	Loury	Employment of sulphurous acid; obtained by burning sulphur.
1854	Bellfort . . .	Provisional protection for the use of sulphurous acid with a minute quantity of hydrochloric acid, to prevent the sulphurous acid combining with the alkaline salts of the meat, and so giving rise to a disagreeable flavour. The acids were used in solution, and the meat immersed in it.

List of the principal Patents for the Preservation of Food—cont.

Date.	Method and Name.	
	By chemical agents.	
1855	Brooman, Demait, and Hands.	Employment of sulphurous acid in a gaseous state, the substance being suspended in a closed chamber.
	Gamgee . . .	Would cause the animal to inhale carbonic oxide gas, and when nearly insensible it should be killed. The carcase is to be suspended in an air-tight chamber, from which the air is removed, and is replaced by an atmosphere of carbonic oxide gas, to which a little sulphurous acid has been added. After being thus exposed for 24 to 48 hours, it is to be hung up in dry air. It is said that meat thus preserved will keep several months.

CHAPTER III.

WATER AND ITS IMPURITIES.

SINCE water enters more or less into the composition of all articles of food as well as drink, and is employed in many cases as an adulterant, as, for example, in milk—to which sometimes it communicates the germs of disease—and in spirits; and, further, since Food Analysts are constantly called upon to make analyses of water, it becomes not merely necessary that the subject should be fully considered in any comprehensive work dealing with adulteration, but that the first place should be assigned it in such a treatise.

Chemically pure water consists of a definite combination of hydrogen and oxygen, and anything additional therein contained may be looked upon as foreign matter, and be regarded in the light of an impurity.

Thus viewed, there is really no absolutely pure water to be found in nature; ice, snow, rain, and distilled waters are the nearest approaches to purity, and yet they contain no inconsiderable amount of a variety of admixtures and impurities.

1. *Ice water.*—This water, though not absolutely free from contaminations, is yet one of the purest waters in nature, owing to the very remarkable and beautiful fact, that in freezing, which is an act of crystallisation, all, or nearly all substances, or impurities, gaseous, organic and mineral, are cast out, and are to be found in the unfrozen portion of the water; the absence of the usual gases renders, however, ice water somewhat flat and insipid. A well-known illustration of this fact is afforded by icebergs, which, although formed from the sea, yet when melted consist of water in a state of great purity. Another illustration is afforded by the method adopted in northern countries to obtain salt from the sea. The water being frozen, the salt is found in the briny mother-liquor which remains, and from which it is obtained by crystallisation. We have recently come across a third illustration of the same principle in the artificial production of ice on a commercial scale, by the low temperature produced by the evaporation of ether. In this case we submitted both the ice and the water from which it was produced to analysis with the striking results given on the next page, it being understood that only a small portion of the water actually employed was transformed into ice.

Analyses of ice and the water from which it was obtained:—

	Original Water.	Ice.	Water left.
Total solids	27·0	3·0	14·2
Chlorine	1·94	0·90	—
Lime	10·53	trace.	14·11

2. *Snow water.*—It follows from what has already been said, that the water derived from the melting of snow is also soft and pure, but much less so than that obtained by the melting of ice, since many of the impurities are retained on the surface of the small and innumerable crystals of which snow is formed.

3. *Rain water.*—It will be readily understood that rain water will in most cases be found to contain various impurities, these being taken up by it from the atmosphere in its descent to the earth. These impurities are for the most part of a gaseous and organic character, and, of course, their exact nature and quantities will vary with the condition of the air at the time when the rain falls. The principal of these impregnations and impurities are oxygen, the proportion of which sometimes amounts to 32 per cent. of the whole of the dissolved gases, or to considerably more than occurs in the atmosphere itself—namely, 21 per cent. (this difference arises from the greater solubility of oxygen in water) nitrogen, carbonic acid, ammonia, carbonate of ammonia, nitrogenous organic matter, nitrite and nitrate of ammonia and hydrochloric acid; and in towns, carbon, sulphurous and sulphuric acids, and sometimes sulphuretted hydrogen, derived from the coal fires. According to Parkes, the total nitrogen from the nitrogenous salts amounts to 0·0985 per 100,000. Boussingault found 0·4 part of ammonia in 100,000 parts of rain fallen in Paris, and 0·079 in that from the country. Barral obtained from 0·2 to 0·3 in Paris rain water. Bineau found in Lyons even as much as 3 parts in 100,000.

According to Boussingault, the average amount of nitric acid is 0·02 in 100,000. During a hailstorm he found the rain to contain 5·5, and the melted hail 8·3 of that acid, owing to the highly electric state of the atmosphere—a condition which is attended with increased oxidation. On other occasions he met with from 0·04 to 0·21 in rain water. In the country he found only from 0·004 to 0·028. Barral met with from 0·2 to 3·6 in Paris. This latter observer obtained from 0·78 to 2·2 total solids from rain water.

The following analyses of Dr. Angus Smith show the nature and the varying quantities of the principal of the contaminations to which rain water is so subject:—

Rain Water.—Average Impurities per Million Parts.

Where collected.	Hydrochloric Acid.	Sulphuric Acid.	Sulphuric Acid for 100 Hydrochloric.	Free Acids calculated as Sulphuric Acid.	Ammonia.	Albuminoid Ammonia.	Nitric Acid.	Oxygen required as Permanganate.
Ireland, Valencia . .	48·67	2·73	6	None	·18	·03	·37	·05
Scotland, five sea-coast country places, west .	12·28	3·61	29	·14	·48	·1	·37	·02
Scotland, eight sea-coast country places, east .	12·91	7·66	59	2·44	·99	·11	·47	·65
Scotland, twelve inland country places . .	3·38	2·06	61	·31	·53	·04	·31	·26
England, twelve inland country places . .	3·99	5·55	138	None	1·07	·11	·75	·47
Scotland, six towns (Glasgow excluded) . .	5·86	16·50	282	3·16	3·82	21	1·16	1·86
Darmstadt	·97	29·17	2998	1·74	—	—	—	—
London	1·25	20·49	1645	3·10	3·4	·21	·84	—
England, six manufacturing towns . . .	8·70	34·27	394	8·40	4·99	·21	·85	2·74
Manchester . . .	5·83	44·82	768	10·17	5·96	·25	1·01	3·22
Glasgow	8·97	70·19	782	15·13	9·10	·30	2·44	10·04

Barral found 0·78 to 2·2 total solids in 100,000 parts, and Moleschott as the mean of five samples of water, per 100,000, 3·2 to 2·24 grains per gallon. But it must be remembered that rain water, which passes over the roofs of houses before being collected, or which is retained in cisterns of any kind, acquires further and especially mineral and metallic impurities, notably lead and zinc.

4. *Distilled water.*—By distillation water is freed from a great many of its impurities, and is obtained in a comparatively pure condition; this will vary, however, with the water from which it has been distilled; the purer the water used for distillation, the better will be the distillate. Of course any volatile constituents present in the water will pass over, and as most waters contain more or less ammonia—either free or as carbonate or nitrite—these will be found in the first portion of the distillate, as also in some cases other volatile impurities of an organic character. Hence it is very necessary that the chemist should in all cases satisfy himself of the purity of the distilled water he uses in his laboratory, especially that required for water analysis and the employment of the Nessler Reagent.

The distillation of water is carried out on a large scale on board many ships, it being prepared from sea water. The water thus obtained sometimes contains a little free hydrochloric acid derived from the decomposition of the chloride of magnesium.

The water so purified being deprived of carbonic acid and oxygen, requires, before it becomes palatable, to be re-aërated. This object is effected by an apparatus specially devised by the late Dr. Normandy, and which is much employed on board ship.

Now, water possesses to a considerable extent the power of absorbing and holding dissolved a great variety of gaseous and solid matters; these are sometimes poured directly into the water, but usually they come into contact with it in its passage over or through the various strata or substances of which the earth is composed.

In this way all water becomes more or less contaminated or impregnated with a variety of impurities, which may be divided into three classes—the *inorganic* or *mineral*, the *gaseous*, and the *organic*, the nature of the principal of each of which we shall next consider.

THE MINERAL CONSTITUENTS.

The ordinary *mineral* constituents present in water are *lime*, *magnesia*, *soda*, *potash*, and *ammonia*, with frequently *iron* and *alumina*, which are bases, and *chlorine*, *sulphuric*, *carbonic*, *nitrous* and *nitric*, and sometimes *silicic* and *phosphoric* acids, which are for the most part in union with these bases, though most waters contain considerable quantities of uncombined carbonic acid as well as of air. Now, these several bases and acids are variously combined, producing a variety of resulting salts; but most potable waters contain *carbonate of lime*, held in solution by excess of *carbonic acid*, *sulphate of lime*, or of *soda*, and *chloride of sodium*, or *salt*.

Now, none of these salts are injurious in themselves, unless when present in considerable amounts; still they afford valuable evidence in many cases of the impurity of water, since a large excess of sulphate of lime and chloride of sodium is usually indicative of contamination by sewage. Not necessarily so; but when these salts not merely occur in large amounts, but are also associated with certain organic matters to be noticed hereafter, the evidence of impurity is complete. It is found, as a matter of experience, that the two kinds of impurity often go together; thus chlorine, sodium, and sulphuric acid, in their combined state, are all derived largely from our food; from this they pass into the excreta, thence into the sewers and soil, and finally into rivers and surface-wells, which are still too often the sources of our water supply. Whenever, then, chloride of sodium and sulphate of lime are present in a water in large amount, together with any considerable quantity of the organic matters presently to be noticed, we may, as a rule, safely pronounce the water to be impure, and to have been subject to sewage contamination.

Lastly, a very common constituent of our food is phosphoric acid, in the combined state. Should this, therefore, be discovered, even in the minutest amount, in a drinking water, its presence may be safely accepted as evidence of pollution by sewage.

So much for the significance to be attached to the presence of inorganic or mineral matter in water.

THE GASEOUS CONSTITUTENTS.

The *gaseous* impurities are chiefly *oxygen, carbonic acid, nitrogen,* with occasionally *carburetted* and *sulphuretted hydrogen.*

The soil is said to contain two hundred and fifty times as much carbonic acid as the air. This acid is, of course, readily absorbed by the water, when in its turn it acts upon and dissolves various substances with which it is brought into contact by the descent of the water through the earth.

THE ORGANIC CONSTITUENTS.

We will now turn to the consideration of the organic materials and derivatives found in water—namely, *albuminoid matter* in solution, *dead and decaying organic matter* in suspension, and various *living productions* belonging both to the *vegetable* and *animal* kingdoms. The principal and most important substance found is albumen, or some allied albuminoid matter. This has usually several sources. Thus (1) the decay of vegetable and animal remains in the water itself; (2) vegetable and animal matter received from ditches and dykes, and dissolved out of the earth by the rain-water in its passage to a river; (3) the discharge of sewers into the water; (4) the entrance of human excreta independent of sewers; (5) the refuse of many manufactories on the banks of rivers.

But this albuminoid matter, so long as it is undecomposed, and retains its integrity, is innocuous. Nobody finds fault with it in his soup, or suspects it of producing fever; and yet in this it exists in quantities of course far exceeding that present in even the very worst of waters.

Like, however, other allied organic substances, it speedily undergoes decomposition, resolving itself in part into nitrous and nitric acids, and ammonia. In the first place, therefore, the quantity of the albuminoid organic matter affords a most conclusive and important test of the quality of the water, and in the second, the amounts of the nitrous or nitric acid and ammonia which are derived from the albuminoid matter.

We stated that the undecomposed organic matter of water is non-injurious, and the same must be said of the nitrites and nitrates when not in very large amounts, and ammonia; but the fact really is that the nitrogenous matter in water is constantly undergoing change, not only being converted into the acids and volatile alkali above named, but into other compounds, the nature and properties of which are for the most part unknown. Even if it does not give rise itself to injurious compounds, it may possibly supply the food necessary for their formation or development.

But waters also contain *non-nitrogenous* organic matters, the nature of which is but little understood, and the amount of which is but seldom estimated, except by Dr. Frankland, and those who adopt his process of water analysis; but we are of opinion that anything like a complete and practical analysis should embrace such an estimation.

Some of these non-nitrogenous matters have been described as consisting of *humin*, *ulmin*, and of the acids derived therefrom, as *humic*, *ulmic*, *crenic* and *apocrenic* and *geic acids*, all of which are stated to combine readily with ammonia.

Other organic acids which have been found in much contaminated waters are the following fatty acids: *formic*, *acetic*, *proprionic*, *butyric*, and *caproic acids*. As much as 1·5 gramme per litre, or 105 grains per gallon of *butyrate of lime*, have been detected by Schweitzer in the water of a much contaminated well. Lastly, waters frequently contain organic *colouring matters*, extracted for the most part from decaying vegetable matter, as from peat.

ON WHAT DO THE INJURIOUS PROPERTIES OF SOME WATERS DEPEND?

Now, since none of the compounds we have named possess injurious properties in themselves, on what do the well-ascertained powers of a water to produce disease depend?—what confers on the water its destructive and lethal power? The answer to this all-important question is unfortunately not so clear and definite as we could wish. But it is a fact, well attested by the concurrent evidence of many observers, that the waters which have been proved to give rise to disease are those in which the organic or albuminoid matters and their derivatives most abound. Again, it cannot be questioned but that the power of water to disseminate disease arises, in most cases, from the fact of that water containing the *materies morbi*, possibly the *germs*, of the disease itself.

We are, then, entitled to demand, on the ground of experience, that the water we consume for drinking purposes should be of the highest standard of purity obtainable; and we will hereafter attempt to fix what, in our judgment, should be that standard.

THE HARDNESS OF WATER.

The *hardness* of a water mainly depends upon the amounts of *carbonate* and *sulphate of lime* present, the former giving rise to what is called *temporary* hardness, because it is, for the most part, removed by prolonged boiling, by the precipitation of the carbonate of lime through the expulsion of a portion of the carbonic acid; and the latter to *permanent* hardness, because it is not thus removable, but the *chlorides of calcium* and *magnesium* and the *nitrites* and *nitrates* of the same bases also contribute, in many cases, to the hardness of a water.

Now a hard water is injurious for drinking, because its powers as a solvent for the food are impaired, and because it is taken up by the absorbents of the stomach with much greater difficulty than a soft water; thus impeding digestion. Further, a hard water is bad for cooking, because of the impairment of its solvent or extractive properties. It is also bad for washing. 'Each degree of hardness indicates the destruction and waste of 12 lbs. of the best hard soap by 100,000 lbs. of water.' (*Frankland.*)

The carbonate of lime in water decomposes about ten times its weight of soap in washing—more exactly, 8·8 of white curd soap, and 10·7 of common yellow soap; and other salts of lime act injuriously upon soap in proportion to the lime they contain, the soluble soap, *stearate* and *oleate* of soda, being converted into an insoluble and useless compound, stearate and oleate of lime: the water, then, is deprived of lime, or softened, at the expense of the soap. The lime in 100 gallons of Thames or New River water thus occasions the destruction of about 34 ounces of soap before any portion of it becomes available as a detergent.

The Chemical Commission of 1851 treated fully of this subject, especially as connected with the Metropolitan water supply, and their evidence was to the following effect:—

'The softer the water the better it is adapted for washing with soap, the earthy salts present causing a definite and calculable loss of soap, which may be taken as amounting, in every gallon of water used in washing, to 10 grains of soap to each degree of hardness of the water. Thus, with one gallon of Thames water of 14 degrees of hardness before boiling, the loss of soap would be 140 grains, and at 5 degrees of hardness, after boiling, the loss of soap would be 50 grains; or with 100 gallons of water, the loss in the first case would be 32 ounces, and in the second about 11½ ounces.'

Taking the whole quantity of soap used in the washing of linen, first to soften the water, and afterwards to cleanse the linen, the Commissioners estimate the loss at 42 per cent. when the water is employed cold, and 14 per cent. with woollens; or where the same water is softened by boiling, at 20 per cent. for linen, and 5 per cent. for woollens.

Now there is a great fallacy or source of error pervading the calculations as to the loss of soap, arising from the use of the boiled water. Much of the water thus used has not been softened to anything like five degrees of hardness; and hence the destruction of soap is much greater than that stated in the calculations above given.

Now, the hardness of the London waters has led to the extensive employment of soda. This precipitates all salts of lime, and so softens the water, and therefore effects a great saving of soap; but the soda costs something, and it exerts a highly injurious effect on the fibre of the linen or cotton, as also on the colours of certain prints.

Further, the Commissioners state, 'It is found proper to avoid boiling any portion of the Thames water that is used in the wash-tub, or even heating the water above a certain point; for the carbonate of lime precipitates on the linen, carrying down the colouring matter of the water with it, producing stains which there is the greatest difficulty in afterwards removing from the linen. The colour of the water is thus, indeed, fixed upon the cloth by the precipitated lime with the tenacity of a mordant. The evil of the hardness of the water is, therefore, aggravated by the *flood-tinge*, or *clay-colour*, which the London waters often exhibit for several months in the year.

'The number of gallons of water generally used with a certain weight of soda is considerably greater in London washing than in the practice of the Lancashire bleachers, so that the waste of soap from hardness cannot fall below, but may exceed, the previous estimate.

'In the washing of the person the saving of soap by the use of soft water is most obvious. For baths, soft water is most agreeable and beneficial, and might contribute to their more general use. Its superior efficiency to hard water in washing floors and walls is calculated also to promote a greater cleanliness in the dwellings of all classes, both within doors and externally.'

The witnesses examined on this point were Mr. Bateman, Mr. Hawksley, Mr. Rawlinson, Mr. Way, Mr. Duncan, Dr. Letheby, Dr. Playfair, Dr. Parkes, Mr. Samson, Dr. Frankland, Dr. Odling. Dr. Miller, Dr. Angus Smith, and Mr. Heron. They all concur in the great advantages of the use of soft water for the washing of linen and of the person, for dyeing, with some exceptions, and for many manufacturing purposes. Dr. Letheby, in estimating the loss of soap, proceeds on the basis that all the heated river water used is reduced to a uniform standard of 5 degrees of hardness. In reference to this point, Dr. Frankland states that he considers '*the advantages of temporary over permanent hardness have been considerably overrated, as water used hot for domestic purposes is either not boiled or boiled for too short a time to produce the full softening effect.*'

With respect to the effects of hard water upon health, Dr. Parkes gave the following evidence before the Royal Commission on Water Supply of 1869:—

'With regard to the effects upon health of the use of hard waters, distinguishing between the carbonate of lime water and the sulphate of lime and sulphate of magnesian waters, the carbonate of lime waters appear, in some cases, certainly to produce some effect upon health—for instance, dyspepsia; and they do not agree with some class of persons, whereas to others they appear quite harmless. There is a large population living upon chalk water, and we cannot trace any very decided effect upon their health in the production of any class of disease—calculus, or anything of that kind; but at the same time persons do sometimes suffer from indigestion.' When asked 'Would 16 or 20 degrees of hardness be prejudicial?' he replied, 'I think that degree of hardness would be certainly prejudicial. I think that very probably it might disagree with a great many persons; but supposing it reached to 8 or 10 or 12 degrees of hardness from carbonate of lime, it might be considered probably good water so far as that was concerned; but I should draw a marked distinction between that and the hardness arising from sulphate of lime, or sulphate of magnesia or chloride of calcium, which would certainly disagree in much smaller quantities: so that the goodness of water for drinking purposes I would estimate according to its permanent hardness rather than its temporary hardness.'

Pressed with other questions, the witness replied: 'for troops, in all cases we should prefer a soft water, if it were possible to obtain it.'

'Speaking generally, you are of opinion that the mere presence of carbonate of lime of 15 degrees of hardness would not be injurious to health?'—'With 15 or 16 degrees of carbonate of lime hardness, I should say that it would be a hard water, and with some persons it would disagree and produce dyspepsia. I think it should not exceed 10 or 12 degrees, if possible. At the same time, I should wish to state that I would prefer water free from that even.'

For many years past we have never lost an occasion to advocate the use of soft water in preference to hard; and we have more than once treated of this important subject in the pages of 'Food, Water, and Air.'

The introduction of soft water for the use of towns and cities met with, at first, great opposition, and this from quarters whence it might have been the least expected; namely, on the part of some medical men and chemists. It was affirmed that the lime of the water was necessary to the growth of the bones, that without it they would become soft; and, indeed, that the whole frame without a powerful osseous skeleton would become weak and stunted. Those who made use of this argument forgot that phosphoric acid is as necessary to the bones as lime, and that water does not furnish a particle of this acid to the bones, it being obtained from the various articles of food consumed; and if a sufficient supply of phosphoric acid be obtainable from this source, why not the requisite quantity of lime?

For a long time this objection to the use of soft water prevailed, and prevented, in many cases, its introduction for the supply of towns. In some quarters the notion still lingers, and this groundless objection continues to be urged with pertinacity, especially where interest points to the use of hard water. That it is without any real foundation has now been proved by the experience of those towns which have for some years been supplied with soft water.

A further objection persistently urged against the employment of soft water for a town supply is the liability of such water to act on lead piping. But experience has also shown that this fear has been greatly exaggerated.

Liverpool, Manchester, Newcastle, and many other cities are now supplied with very soft water and this without any detriment to health.

Here then we have a large body of evidence of a very clear and convincing character all in favour of the use of a soft water.

It is therefore abundantly established that hard water is wasteful of soap in the washing of linen; that it renders the operation more laborious and less effective; that it is injurious to the linen itself; that it is wasteful of soap in personal ablutions, besides being far less agreeable and efficient; and, in fact, that it is objectionable for cleansing purposes generally, and that it is a serious hindrance to the sanitary use and effects of such water.

THE SOFTENING OF WATER.

Many years since the late Professor Clarke, of Aberdeen, took out his well-known patent for softening water.

The principle of this process consists in adding a solution of caustic lime to the water to be softened. The effect of this is, to abstract a portion of the carbonic acid from the carbonate of lime in solution, both portions of lime being thus brought into the condition of a neutral carbonate, so little soluble is water, and which hence becomes gradually precipitated.

The water to be softened is divided into two portions, a larger one consisting of about three-fourths and a small one of one-fourth. The larger quantity is rendered decidedly alkaline by the addition of lime water, and then the second portion is added to it.

The quantity of lime water required is thus determined for each water for which the process is employed. The alkali may then be added with frequent stirring to the great bulk of the water to be softened, as contained in one or more reservoirs, lined with concrete. Care must be taken to render the water as nearly neutral as possible, as any excess of free lime would be very objectionable, and this may be guarded against by the employment, as indicator, of a solution of nitrate of mercury, added to a small quantity of the water, the black sub-oxide of mercury being thrown down on the addition of the alkali.

This process does not of course remove the lime from those combinations which give to water its permanent hardness; but since usually the greater portion of the hardness of a water is of the temporary character, it is in most instances highly effectual in the softening of a water, often removing nearly the whole of the hardness.

The Chemical Commission of 1851 recommended the adoption of this process to the Thames water with which London is supplied, and they estimated the cost at about 20*s.* per million gallons of water.

The process has, in fact, been applied in several instances to the softening of the water supply of towns with very great success and advantage. And it may be said, in further recommendation of it, that it not merely softens the water, but that it also purifies it to a considerable extent, the carbonate of lime carrying down with it all the suspended organic matter, with but a small portion only of the dissolved organic matter.

The carbonate of lime obtained by this process should be collected, made into cakes and sold. It is often of a superior quality, and its sale would repay part of the cost of the process itself.

ON THE QUALITY OF WATER.

The quality of a water and its suitability or otherwise for domestic use depend first upon the nature and quantity of the several *mineral constituents* which enter into its composition, and secondly, on the *organic ingredients,* in *solution,* in *suspension,* or in the form of *living organisms.*

It has been shown that all the salts of lime and magnesia found in water render it hard, and therefore if they are present in considerable amount, the water is thereby rendered unsuitable for drinking, cooking, and washing.

Other mineral constituents of water, which, if present in anything like considerable amount, are to be viewed with suspicion, are the chlorides, especially *chloride of sodium,* and the sulphates, particularly *sulphate of lime.* The reason of this is, that while there are but few natural sources of sulphates and of chloride of sodium, they are abundantly contained in the excreta, and make their way into our drinking water either by percolation through the soil, or by being cast as sewage into our rivers and streams, which are too often the source of our water supplies. Dr. Angus Smith, in his evidence before the Royal Commission on Water Supply in 1869, thus refers to the occurrence of nitrates and chloride of sodium in waters. The nitrates, he says, 'are what I have called *Old Organic Matter.* Where nitrates are caused by matter from animals, there is always a corresponding amount of common salt. Men take from 200 to 300 grains at least of common salt every day, and it is given out every day. This is the most unchangeable accompaniment of sewage. Whenever chlorine is largely in water, it is necessary to look for nitrates derived from sewage; and, as a rule, it is so constant that there is scarcely any exception. When we find much more than the average quantity in a well-water, nitrates are found also, and if the water in a district is pretty well known—that is to say, if the amount of chlorine in water from any district is pretty well known, and a specimen of that water should indicate rather more chlorides than usual—you may conclude with almost certainty that it is from sewage.'

With regard to its organic constituents any considerable amount of *albuminoid organic matter* renders the water unfit for use, and the same may be said to a certain extent of the organic matter suspended in water, and especially of the living productions which impure waters so frequently contain in such abundance. But it must be remembered that in this latter case this dead and living organic matter is capable of being removed to a large extent by an efficient process of filtration.

Another circumstance to be taken into consideration in expressing an opinion as to the quality of a water supply are the fluctuations in the amounts of the nitrogenous organic matter found in certain waters, especially river waters in summer and winter. These are shown in the analyses of Drs. Frankland and Odling, made for the Royal Commission on Water Supply, 1869, to be very great and remarkable.

	Thames below weir, at Staines.		Filtered Thames water at Hampton.	
	May 2nd.	Oct. 28th.	May 4th.	Oct. 28th.
In 100,000 parts organic nitrogen .	·027	·097	·024	·057
Ditto carbon . .	·304	·304	·260	·263

The following causes appear to us to afford some explanation of this striking difference, and to account for the much larger quantity of albuminoid organic matter in winter. First, the streams and floods of winter which wash out the dykes and ditches in communication with the Thames; second, the death and decay of many forms of vegetable and animal life; third, the diminution in the amount of minute and infusorial life in the water; and, fourth, the slower decomposition and destruction of the organic matter in winter.

The presence likewise in considerable amounts of *ammonia*, *nitrous*, and *nitric acids*, derivatives of urea and albuminoid matter, would also serve, especially when taken in conjunction with other unfavourable results of analysis, to condemn a water. With respect to nitrous and nitric acids in water much has been said and written, and much discussion has taken place as to their significance and importance in potable waters.

PURIFICATION OF WATER.

Impure water, when left for a time, undergoes two different processes of purification. The one results from the *decomposition* of the organic matters contained in the water, and their breaking-up into ammonia, carbonic acid, sulphuretted hydrogen, &c.; the other is due to the *oxidation* of that matter, the oxygen being derived from the air continually absorbed by the water. This process of oxidation is, of course, greatly promoted by the motion and agitation of the water, as this brings the oxygen into more intimate contact with the organic matters in solution.

Both these methods, judged by their practical results, and especially the latter, are highly important; and were it not for them, disease resulting from the drinking of impure water would be of much more frequent occurrence than it now is, and it is only of late years that the importance of the purification of water by oxidation has been at all adequately recognised. But even now the extent and limits of its operation are but ill defined, and exact experiments are still required to test its full value.

In reference to this question of the purification of water by oxidation, Dr. Letheby made the following statements in evidence given before the Royal Commission on Water Supply in 1869, when asked the question, 'Have you at all ascertained in what length of time or distance polluted matter will be decomposed and transformed in its chemical qualities; for example, supposing we had the sewage from Richmond poured into the Thames, how far down the river would it be lost as sewage and broken up into other chemical elements?' he thus replied: 'I have made a very great number of chemical experiments to determine that. I have examined most of the rivers in England, and this is the conclusion that has been come to, not only in my mind, but *in the minds of all the engineers who have devoted their attention to this subject,*—that if ordinary sewage, containing, we will say, nearly 100 grains of solid matter per gallon, such as our London sewage, out of which probably something like 14 or 15 grains are organic, be mixed with twenty times its bulk of the ordinary river water and flows a dozen miles or so, there is not a particle of that sewage to be discovered by any chemical processes.'

Mr. Wanklyn gave the following evidence before the Royal Commission in reference to the same matter. In reply to the observation: 'Q. 5482. It has been stated in evidence before us that if you pour into water a volume of sewage equal to 5 per cent. of the volume of water into which it is cast, the water will so operate upon it in deodorizing and destroying, and breaking up its elements—into its primitive elements, in fact—that it would no longer be sewage, or possess any of its noxious qualities. You apparently hold a contrary opinion?—This I am sure of: the urea in the sewage in such a water would be very readily broken up into ammonia and carbonic acids, and a little exposure would dispose of the urea; but the albuminoid matter in sewage is extremely persistent, and one of the results of the whole investigation is this, that albuminoid matter is very persistent indeed, and you could not depend upon any treatment such as you have mentioned getting rid of the albuminoid matter.

'5485. But will not certain changes take place even in the albuminoid matter?—Yes, certainly; but the change is very slow, and it is very irregular.'

Of the evidence of Dr. Frankland, the following questions and answers embrace the more important parts:—

'Q. 6222. What does your experience tell you is the effect of the quality of the present supply in London on the health of the population generally?—I cannot, of course, trace any direct connection between the present supply and the health of the population, but I consider that water contaminated with sewage contains that which is noxious to human health. There is no process practicable on a large scale by which the noxious material can be removed from water once so contaminated; and therefore I am of opinion that water which has once been contaminated by sewage or manure matter is thenceforth unsuitable for domestic use.

'6226. You state that you have come to the conclusion that sewage has been the cause of the contaminations of this water, because you find a skeleton there in the form of nitrates and nitrites?—Yes; and also of ammonia, which I think I omitted to mention; but that is a very insignificant part of the skeleton.

'6227. Is it possible that those nitrates and nitrites could be present in the water without its having been contaminated with sewage? Could they be produced by some other cause than that of sewage?—They could be caused by manure thrown into the water, or by manure applied to the land.

'6228. But are they attributable to nothing else?—No; nothing else, I believe.

'6223. With regard to the Kent water, we had some evidence yesterday to the effect that you must have been mistaken in finding traces of sewage in these chalk wells, the water being taken at a depth of 250 feet in the chalk, and the upper part of the wells themselves being lined; therefore the water must have filtered through the chalk; and there could be no trace of the skeleton of sewage. Is it your opinion that the skeleton of sewage, as you describe it, will find its way down to a depth of 250 feet, and that after filtration through gravel, and ultimately through the chalk, its presence will still be detected?—There cannot be a doubt about it, that this skeleton of which I speak, but which is a very different thing from the sewage itself, is present. I have never stated that the water which has filtered through the chalk in this way contains unaltered sewage; it is this imaginary skeleton of sewage that I find in water so filtered.

'6240. The presence of what other elements would lead you to a conclusion upon the quality of water as injurious to health?—In the first place, when water is once contaminated with sewage, there is no process to which it is afterwards subjected which will effectually remove all that sewage contamination from the water; filtration will not do it, in certain cases, at all events. I have found the excrements of cholera patients cannot be filtered out of water; that after a degree of filtration which I believe is never attained by the water companies, and rarely attained, perhaps, by the passage over soils in irrigation, this water still remains opalescent from the rice-water evacuations with which it has been mixed. The degree of danger which still remains in waters from different sources varies, obviously, according to the amount of filtration that the water undergoes. I would much rather drink the chalk water of the Kent Company, even if it had been contaminated to four times the extent of the Thames water, than I would drink the Thames water; because, if I could have the assurance that none of that sewage or manure water had found its way into the well through fissures in the chalk, the chalk water having passed through say 100 feet of chalk, would be very much better filtered than any water which finds its way to the Thames.

'6292. You conclude that it is a very difficult thing to get rid of sewage matter by running water?—I do. That portion of it which remains undecomposed after its passage through the sewers oxidizes with extreme slowness.

'6297. Did I rightly understand you to say that you cannot distinguish in those cases whether it (the organic nitrogen) is derived from vegetable matter or from animal matter?—I have said that until recently it had been impossible to distinguish between the two; but that now I considered that the proportion between the carbon and the nitrogen in the two cases afforded a basis from which we could in many instances decide.

'6328. It would seem that you cannot very well refer the presence of nitrates and nitrites in the water exclusively to previous sewage contamination.—[After alluding to the presence of materials in rain-water which may furnish a small quantity of nitrates and nitrites, Dr. Frankland observed]: But it is a remarkable circumstance that waters which it is well known cannot be contaminated by manure or by sewage, never do contain those nitrates in a proportion bringing them near to the point of contamination.

'6372. Then you do not accept the theory that sewage discharged at point A, and travelling down the river, is so oxidized as it passes a distance of six or seven miles, and is so entirely destroyed, that its original elements are not to be found; but it is converted into some other substance or substances which are not detrimental to human health?—I believe that it is by no means a generally true proposition.'

Dr. Odling's evidence was to the following effect:—

'Q. 6448. Have you found in those examinations of the Thames water the presence of sewage not decomposed?—I have not.

'6451. Has your attention been directed to the important principle of the self-purifying process which is going on in rivers running at a given velocity?—Yes, it has. There may be great difference of opinion as to the degree to which that self-purification takes place, but that it does take place to a very considerable extent I think is undeniable.

'6462. Is it your opinion that those (nitrates) which have been found in chalk water are due to sewage?—It is a point upon which there is no positive evidence, but I am inclined to think that it is not so, for we find them distributed so irregularly. For instance, the deep-well water at Trafalgar Square and the deep-well water from the green sand and the lower chalk, all over London, is nearly free from nitrates and nitrites, whereas the water of equally deep wells elsewhere in the chalk is found to contain very considerable quantities of nitrates and nitrites. The deep-well water from nearly all formations has been found to contain nitrates. Then, moreover, a proportion of the nitrates which the sewage itself undoubtedly does furnish in one case is destroyed, and in another is not; and so far as the history of the water is concerned, in the one case where the nitrates are destroyed that water may show but a very small amount of previous sewage contamination, whereas it might have had a much larger amount than the other.'

The more important portion of the evidence of the next witness, Sir Benjamin Brodie, was to the following effect:—

'6991. Dr. Frankland states very distinctly that water once contaminated with sewage is unfit for human use, and that you will still find what he calls the skeleton of sewage present, although it may have travelled 100 miles, and been exposed to filtration.—I think what is asserted by Dr. Frankland is true, that there are no known causes in existence on which we can adequately rely to remove the sewage from the water. Medical statistics will tell you more about the injurious or non-injurious character of sewage water than any analysis would do.

'7009. Dr. Frankland considers that this organic nitrogen in the London water is of a very different value from that in other waters, because the proportion of organic carbon to the nitrogen in the waters is different?—Yes; this appears to me a very important fact.

'7011. You think that the tests of the greatest delicacy are yet insufficient to determine the points at which sewage ceases to be present? —I will state a case, which is really an absolutely analogous case to the case of water; namely, the case of the atmosphere. You may look at the atmosphere as really a great ocean. Gases from drains are being discharged into this gaseous ocean, just as the water from the drains is going into the river. These gases are so diluted when they get into the atmosphere, that chemical analysis is absolutely impotent to reveal their presence in any given portion of the atmosphere. But nobody can doubt the injurious effects, under certain conditions, of the gases and other organic matters present in the atmosphere. Another most important thing is this, that really there is no reason whatever to believe that the injurious character either of sewage or of gases from a drain depends, fundamentally, upon the quantity of that sewage or of that gas; in all probability it far more depends upon the quality of the sewage—namely, what it consists of. Now, what is the nature of the poisonous matter in the atmosphere or in the sewage? We do not know that at all. Therefore, how can we possibly say when that poisonous matter is got rid of from the water or from the air? It is a question that, with the means at our disposal, it is absolutely impossible to answer; . . . but the question arises, as I said before, whether a prudent person likes to drink water which contains a certain quantity of nitrates and nitrites, or that when analysed is found to contain a certain quantity of organic carbon and nitrogen—water into which you have deliberately put cartloads of sewage at some time or other in its course.

'7041. If water is supplied to a town from a river which in a part of its course has received previous sewage contamination, and if that water is used on a large scale by that town, and produces no ill results, and chemical analysis fail to detect anything unusual in its character, is it not a fair presumption that such water is wholesome, and good water for the use of a town supply?—*The question is whether it can be always and permanently so used. That seems to me to be the real point at issue. We should have found out long ago the injurious effects even of small quantities of sewage if the sewage were always injurious; but that is not asserted. It is only supposed that under certain exceptional conditions, even sewage may become very injurious. The injurious character of a water impregnated with sewage matter might not be discovered for years. You might go on using it for years, and it might not be discovered; and yet you might have some outbreak of disease in the place, which nevertheless might be connected with the use of that sewage water.*'

Following the evidence of Sir Benjamin Brodie came that of the late Dr. Miller and Dr. Angus Smith. From this it is not necessary to quote, but it will be sufficient to observe that these gentlemen supported to a considerable extent the views of Dr. Frankland relative to the nitric acid in water.

The Commissioners themselves make the following observations in reference to the self-purification of streams:—

'But though for these reasons we believe that the organic contamination of the Thames is much less than is commonly imagined, still it would be sufficient to do great mischief, were it not for a most beneficial provision of Nature for effecting spontaneously the purification of the streams. Some of the noxious matter is removed by fish and other animal life, and a further quantity is absorbed by the growth of aquatic vegetation; but in addition to these abstractions, important changes are effected by chemical action. The organic compounds dissolved in the water appear to be of a very unstable constitution and to be very easily decomposed, the great agent in this decomposition being oxygen, and the process being considerably hastened by the motion of the water. Now, as such water always contains naturally much air dissolved in it, the decomposing agent is ready at hand to exert its influence the moment the matter is received into the water; in addition to which the motion causes a further action by the exposure to the atmosphere: and while (as in the Thames) the water falls frequently over weirs, passes through locks, &c., causing further agitation and aëration, the process must go on more speedily and more effectually.

'The effects of the action of oxygen on these organic matters when complete is to break them up, to destroy all their peculiar organic constitution, and to rearrange their elements into permanent inorganic forms, innocuous, and free from any deleterious quality.'

On this pleasing picture we would now offer a few comments.

First, with regard to the removal of some of the noxious matters by fish and vegetables, we would remark, that during their life they perform execretory functions, giving up to the water, products, the nature and properties of some of which are not well ascertained, and the imbibition of which by human beings is not altogether a pleasant subject to contemplate. Again, it must be remembered, that the time arrives when these animals and vegetables die, and aid in the corruption of the water; there is always in every river a vast quantity of decaying vegetable, and not a little animal, matter.

Secondly. Although the oxidising process above described does in time effect the destruction of certain forms and kinds of organic matter, no evidence has yet been obtained showing that it really does destroy the *materies morbi* of cholera, typhoid, and other epidemic and contagious diseases, and of which it has been found that water is a frequent distributor.

Thirdly. Neither has it been proved that the action of oxygen is to convert, even in those cases in which changes are really effected, all the organic substances '*into permanent inorganic forms, innoxious and free from any deleterious quality;*' in fact, the usual effect of the transformation is to convert one series of organic compounds into another of a different nature.

Fourthly. The important fact is overlooked that the apparent purification is in part due, not to chemical transformation at all, but to precipitation. It is in this way that the fæcal and much other suspended matter is removed from running water; it falls to the bottom of the river, fouling the bed, and in its turn polluting the water.

We will now make a few further remarks as to the significance to be attached to the presence of the nitrogenous organic matter, ammonia, and nitric acid found in water. These are in themselves in no respect injurious except when contained in water in very considerable amount; waters are met with which contain but small quantities of such substances, and yet have been productive of disease; on the other hand, waters are in use largely contaminated with such compounds, and which have yet not been known to produce disease. The interest which attaches to the nitrogenous organic matter, the nitric acid, &c., of water, and the reason for determining the quantities in which these are present, lies in the fact taught by experience, that, as a rule, to which there are many exceptions, waters which abound in those substances are those which most frequently give rise to disease; but the *purest distilled water would do the same thing if in any way it were to become contaminated with the infectious or contagious matter of typhoid fever:* and hence the public ought obstinately to refuse to drink water, and especially river water, polluted with sewage, and this although they are assured it has been filtered after the manner usually practised by water companies.

The next point to which we would advert is the interpretation to be put on the presence of nitrates and nitrites in water. Dr. Frankland affirms that they are derived from the oxidation of various kinds of nitrogenous matter proceeding from several different sources, and that their amount indicates the extent of the contamination to which the waters containing them have been, at some time or other, subjected.

Dr. Odling dissents from these views, and thinks there may be other sources of the nitrates and nitrites, but does not indicate a single additional source, while the facts adverted to in reply to question 6462 rather confirm than otherwise Dr. Frankland's views as to the source and origin of those oxidized nitrogenous compounds. It is only when Dr. Frankland bases his estimate of the previous sewage contamination on the quantity of nitrogen thus found that he seems to be at fault; but even here the fault is rather in the opposite direction to that indicated by the objectors to Dr. Frankland's views. Thus in waters containing much vegetation, part of the nitric and nitrous acids, as well as of the undecomposed nitrogenous matter, are absorbed, and so disappear, and are lost to analysis and subsequent calculation.

The late Dr. Miller, like Dr. Odling and one or two other witnesses, expressed the opinion that the nitric acid found in water might be derived from other sources than decaying organic matter, vegetable or animal, in air or water; but Dr. Miller, like other witnesses, failed to indicate any other source than that mentioned, and we believe we may take it as an established fact, so far as relates to the waters in domestic use in this country, that the nitric acid contained in them is invariably derived from organic matter of some kind or other, and it is for this position that Dr. Frankland has so long and ably contended.

Nitric acid in water is, then, really to be regarded as the representative of decayed organic matter; or, as Dr. Frankland somewhat figuratively denominates it, as the skeleton of sewage, and as the evidence, and to some extent the measure, of previous sewage contamination. But this being so, it does not follow that every water containing it, even in large amounts, is to be condemned; on the contrary, supposing the nitric acid to be unaccompanied by nitrogenous matter, and further, supposing the water not to be liable to ready contamination by such matter—as, for example, the waters of the deep wells of Kent —then we may safely presume such water to be safe for use, even for drinking purposes; although this water is too hard to be the type of really the best and most suitable water for domestic use. When, however, a water contains any considerable amount of nitric acid, and at the same time any great amount of nitrogenous organic matter, or, if even free from such matter, is placed under such circumstances as to render it liable to such contamination, then the water should be condemned and avoided.

To the above observations of our own may be added some of the criticisms of the Commissioners relative to the inferences based upon chemical analyses made for them, and especially the conclusions of Dr. Frankland, to which we have already referred at such length.

The Commissioners specially object to the term 'original sewage contamination,' and to the statement that the quantity of nitrites and nitrates found represent the measure of the 'previous sewage contaminations.' They remark that Dr. Frankland refers the origin of the nitrites and nitrates 'not simply to organic matter taken generally, but to sewage or manure matter specially;' and they state, 'this seems to be an inference which can hardly be accepted. It would be perfectly correct if all the nitrogenised matter supplied to the Thames or other waters was after conversion into nitrites and nitrates retained in the water, and if also all those salts could be referred to sewage and manure matter only. But such is not the case. 'All the analyses,' they say, 'show how variable the quantity of those salts is in different parts of the river's course, and that the quantity present at any place is not so much dependent upon the sewage received as the removal which has been effected by vegetation and other causes, by the interference of the tributaries, and by the addition from springs; so that, even supposing them to originate solely from animal matter, the residue affords no comparative results as to the amount of the original contamination. The interfering causes are too numerous to allow us to assign any value to the remainder.'

These strictures of the Commissioners are to a certain extent correct; there is no doubt but that nitrous and nitric acids in water are formed from the decomposition of almost any kind of organic matter, though in sewage-polluted rivers they are doubtless largely derived from sewage, and animal nitrogenous matter; also that these acids once formed disappear from water, from the causes mentioned by the Commissioners. What then we have to bear in mind is that the acids in question take their origin in *nitrogenous organic matter of some kind or other*, not exclusively sewage; and next that 'the interfering causes' are causes of decrease, so that the quantities of nitrous and nitric acids actually found represent usually far less than 'the previous organic contamination.' To get at an approximation of the organic pollution of water, at least three things must be determined: the free ammonia, the nitrous and nitric acids, and the albuminoid or nitrogenous matter.

The Commissioners further observe that the sources, such as springs and wells, most free from possible contamination, show the larger skeletons, that is to say, the largest amount of nitric acid, and, it may be remarked, the smallest amount of undecomposed nitrogenous matter. This, of course, it is important to bear in mind; but still the fact remains, that the nitric acid of springs and wells, however deep, of chalk itself, and of soils, owes its existence to oxidised organic matter, and that the quantity found does really represent a certain quantity of that organic matter. The water of deep wells makes its way into those wells from the surface, carrying down with it organic matter, which, for the most part, ere it reaches these wells, has become converted into nitric acid.

It here occurs to us to remark that in most analyses the oxidized organic matter is put down as nitric acid, and no attempt is made to determine whether the acid really exists in that form or as nitrous acid. Now this is really a distinction of great practical importance, and no chemist, we apprehend, would refuse to condemn a water in which nitrous acid was present in any considerable amount.

Purification by Filtration.

Another highly important means of purification is by filtration. The process of purification which finds its best exemplification in nature—namely, percolation through soils—is more or less imitated in the various methods and media adopted for artificial filtration. The principal of these media consist, of *animal* and *vegetable charcoal*, including that derived from *peat*, *metallic iron*, *magnetic oxide of iron*, *peroxide of manganese*, a mixture of *silica* and *charcoal* or *silicated carbon*, and of *carbon* and *magnetic oxide of iron* or *magnetic carbide*, *sand*, *gravel*, *clay*, and a great variety of porous substances, including *sandstones*, *wool*, *sponge*, &c. Of the mode of action of several of these, special explanations will be given, but many of them act in the two following ways—first, by the removal of suspended matters, and, second, by dividing the water and so bringing it into intimate contact with the air which permeates and fills the interstices of the several filtering media through which the water passes.

Of course, the powers of all filters are limited, and they speedily become spoiled when too much work is thrown upon them at one particular time—that is to say, when water containing a large quantity of organic matter, say six or eight grains per gallon, is rapidly passed through them. In this case the requisite time is not afforded for the due action of the filters, which become simply clogged; but when water containing only a moderate amount of impurity, as one grain per gallon, especially of organic matter in solution, is passed through, then the action of the better filters, particularly those containing charcoal, is not only satisfactory, but continuous. Still, all filters require to be cleansed from time to time, including even those into the composition of which charcoal enters.

Dr. Parkes gives the following directions for the cleansing of domestic filters: 'Every two or three months (according to the kind of water) 4 to 6 ounces of the Pharmacopœial solution of potassium permanganate, or 20 to 30 grains of the solid permanganate, in a quart of distilled water, and 10 drops of strong sulphuric acid, should be poured through, and subsequently a quarter to half an ounce of pure hydrochloric acid in 2 to 4 gallons of distilled water; this both aids the action of the permanganate and assists in dissolving manganic oxide and calcium carbonate. Three gallons of distilled or good rain water should then be poured through, and the filter is fit again for use.'

In order to insure the freedom of the animal charcoal used from phosphate and carbonate of lime, it should be well washed with hydrochloric acid, and should it be desired to ascertain to what extent any charcoal has become deteriorated by use, the nitrogen is to be estimated by distillation with permanganate of soda or potash, or by combustion with oxide of copper.

It is well known that the best of all filtering materials is animal charcoal, as also that its efficiency depends mainly upon its extraordinary absorbing and oxidising properties, and hence this substance enters into the composition of nearly all the portable and domestic filters in use. For details respecting the action of animal charcoal in the purification of water see 'Parkes' Hygiene.' *Metallic iron* in the form of *wire* and *spongy iron* and *magnetic oxide of iron* are all employed in the filtration and purification of water. Their action is mainly limited to the albuminous matters and the nitrites and nitrates in water, which they deoxidise into ammonia. The water is decomposed by the metallic iron, oxide of iron, and hydrogen being formed. This hydrogen combines with the nitrogen of the organic matter to form ammonia. The action of the magnetic oxide is simply that of a reducing agent without decomposition of the water.

Purification by Precipitation.

Another method of purification, which is for the most part mechanical, consists in the precipitation of the mineral and organic matter held both in suspension and in solution in the water. The lime precipitated in Clarke's softening process, as already mentioned, carries down with it no inconsiderable portion of albuminoid matter in solution in the water, and it is affirmed that organic matter is precipitated when calcareous waters such as that of the Colne are mixed with peaty waters, like that of the Way.

We have further to notice another most important means of the purification of water by the development and growth in it of innumerable forms of *living organic productions*, both vegetable and animal, and this we shall do at some length and in the following separate section.

By *boiling* also, water may be purified to a considerable extent, it causing the precipitation, if properly carried out, of the whole of the carbonate of lime which carries down with it a portion of the organic matter, it killing the infusoria and the other living organic productions, and it is also possibly rendering innocuous the animal poisons productive of special diseases; and therefore, should it be necessary to make use of a suspected water for drinking purposes, it should first be *boiled*, and this precaution should never be neglected. Or a few drops of *permanganate* may be added, as it assists greatly in rendering a water pure; and this compound, used in so small a quantity, would not exert any injurious effect. The solution should be added until the water becomes slightly pink, and further small quantities at intervals of three or four hours, until it ceases to become decolorised.

The permanganate readily removes in most cases the offensive smell of impure water, and if this be due to sulphuretted hydrogen, it will be converted into sulphuric acid, sulphates of manganese and potash being formed. With most waters treated in this manner, a precipitate of peroxide of manganese occurs, and this likewise assists in the purification of the water, by carrying down suspended matters.

The action of this test is promoted by warming the water previous to its employment. Waters thus treated sometimes exhibit a faint yellow tint, arising from the suspended oxide of manganese. This is most easily removed by filtration through animal charcoal, but by the use of alum the same object may also be usually accomplished, the combination of the two methods producing more effectual purification. Or, lastly, *alum* only may be added to water, in the proportion of about 6 grains to the gallon. This substance acts best in those waters which contain appreciable quantities of carbonate of lime, sulphate of lime being formed, and these, together with hydrate of alumina, become precipitated, carrying down with them in their descent most of the organic matter in suspension, with a little of that also in solution. No reliance, however, should be placed upon this test for the purification of a really bad and disease-contaminated water. Should a water be deficient in carbonate of lime, a little chloride of calcium and carbonate of soda may be added, and the water allowed to stand for some time.

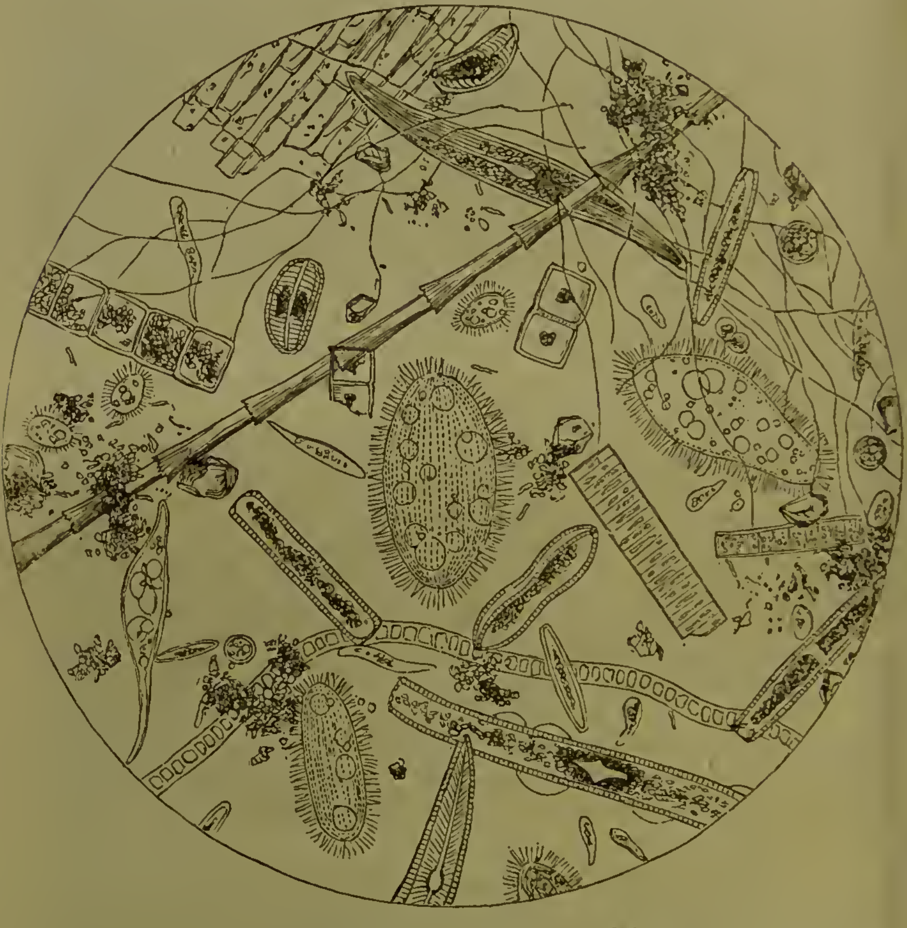
Carbonate of soda boiled with the water contributes in a greater degree to the purification of water than does simply boiling, since not only is the carbonate of lime precipitated by the boiling, but those salts which contribute to the permanent hardness of water are also decomposed, the following reactions taking place. The lime and magnesia of the sulphates combine with the carbonate of soda, forming insoluble carbonate of lime or magnesia, while the sulphuric acid remains in solution as sulphate of soda. The chlorides of the same bases are converted into carbonates, chloride of sodium resulting. Lastly, the nitrites and nitrates of lime of magnesia are likewise converted into carbonates, nitrite and nitrate of soda being formed. It will thus be seen that the chemical action of carbonate of soda in softening water is very complete, and this explains the popularity of the use of soda for washing, cleansing, and even cooking purposes.

ON 'LIVING ORGANISMS' IN POTABLE WATER.

As we were the first to employ the microscope to determine the exact nature of the organic matter held in suspension in many waters, we have some right to express an authoritative opinion of the significance to be attached to the presence of 'living organisms' in potable water.

The suspended organic matter contained in many waters is proved on examination with the microscope to consist of vegetable and animal matter, both dead and living, the dead consisting, for the most part, of particles of decaying vegetable and animal tissues, chiefly the former, and the living of either the sporules or ova, or the fully developed organisms of a great variety of *Fungi* and *Algæ*, including *Diatomaceæ*, *Desmideæ*, and *Conferveæ*; of *Infusoria* or animalcules; of *Entomostraceæ* or water-fleas, of *Annelidæ* or worms, and of countless other productions.

Fig. 1.

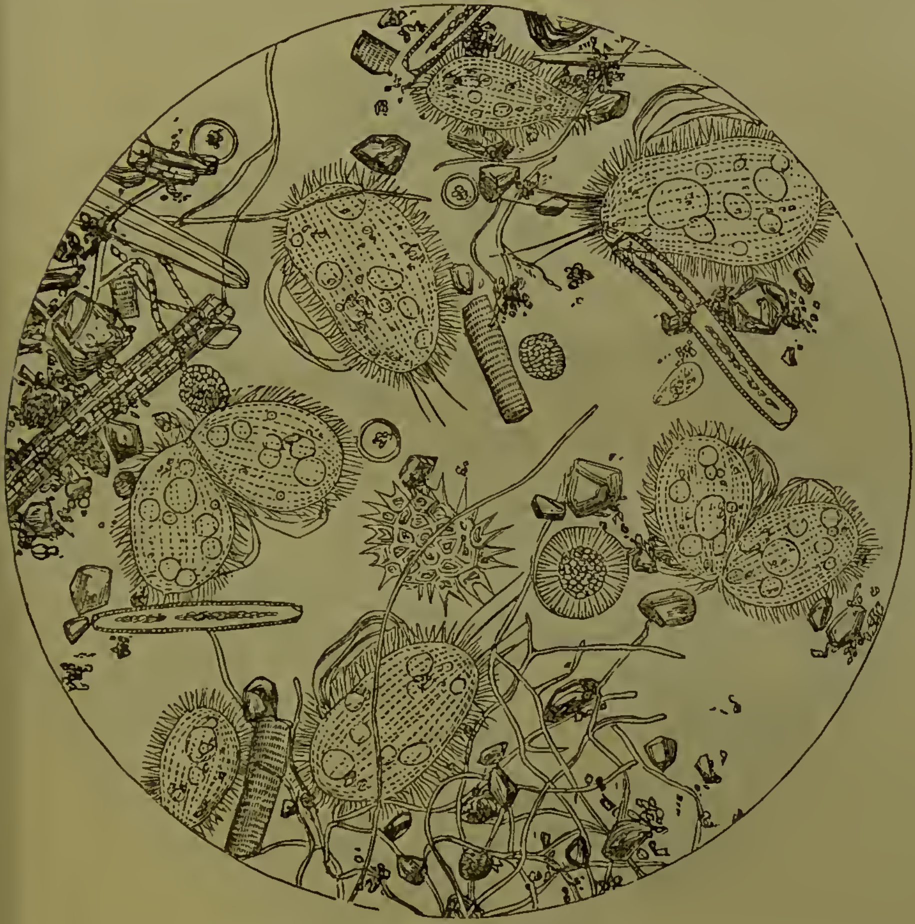


THAMES WATER AT RICHMOND, 1851.

This engraving exhibits the principal *animal* and *vegetable* productions then contained in the water of the Thames at *Richmond*. Drawn with the Camera Lucida, and magnified 220 diameters.

In some waters these several living organisms greatly abound, and, indeed, to such an extent, that from a Winchester quart filled with any such water it would be possible to obtain illustrations sufficient to fill a whole volume. Now, it should be remembered that these organisms, minute as are many of them, are all, or nearly all, to be found elaborately described and figured in a variety of works on natural history, each having its place in a system of classification, and each being distinguished by a scientific name.

Fig. 2.



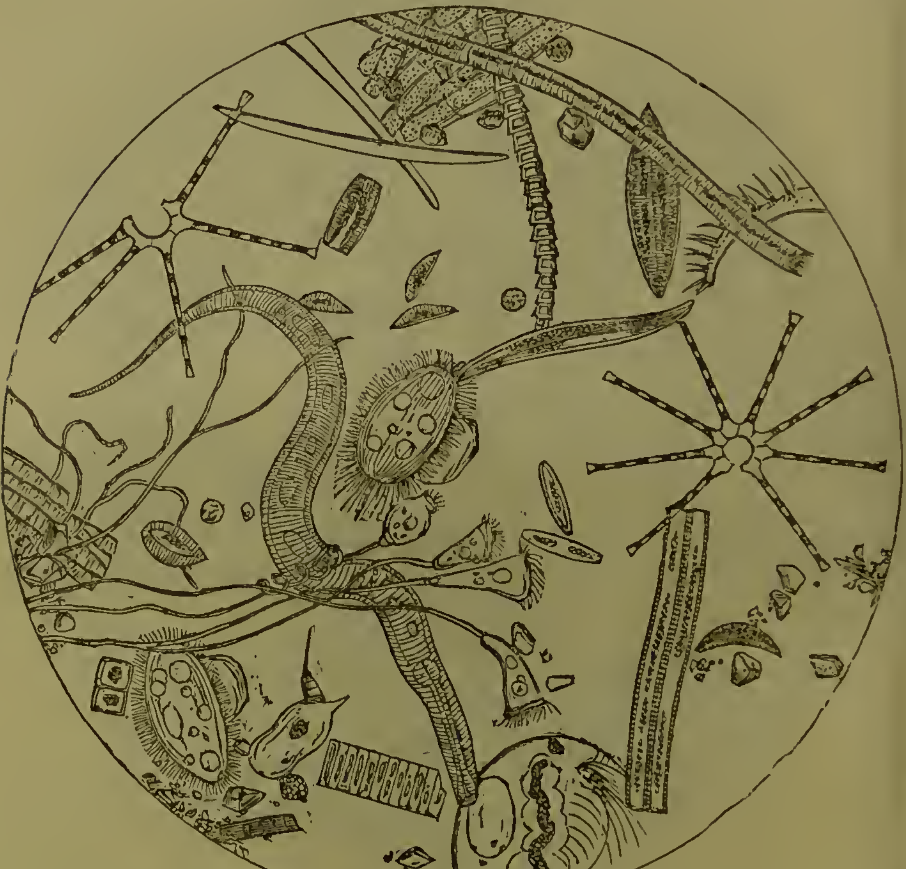
THAMES AT WATERLOO BRIDGE, 1851.

This engraving shows the more remarkable *animal* and *vegetable* productions, dead and living, found in the water of the Thames at *Waterloo Bridge*, including fragments of muscular fibre, magnified 220 diameters.

Now it is especially in the water of rivers, and particularly those contaminated by sewage, that these living productions most abound; these waters may in general be said to swarm with them. They also occur abundantly in the water of ponds and lakes, and occasionally to a much less extent in that of shallow wells; but usually they are absent from such waters, *as they are invariably from those of the deeper and purer springs and wells.*

The purer waters being free from them, they are hence in no respect essential to water; they all contain nitrogen, which they derive from the nitrogenous matter contained in the water, and they are therefore, beyond all question, an evidence of the existence of impurity in the waters in which they are found.

Fig. 3.



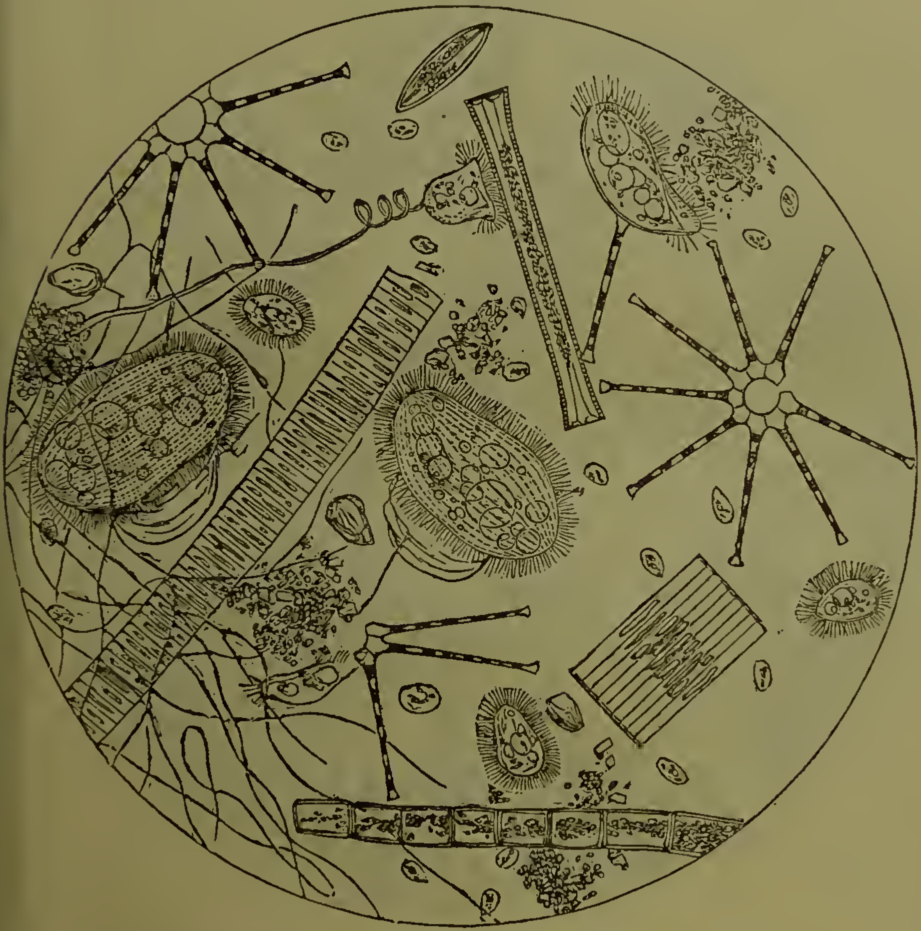
GRAND JUNCTION COMPANY, 1851.

This engraving represents the *animal* and *vegetable* productions then contained in the water as supplied by the GRAND JUNCTION COMPANY. 220 diameters.

That they also help to purify such water by appropriating a portion of the dead organic matter in solution, and fixing it in their own living tissues, and so arresting decomposition, is also true; but those who drink such waters are still under the necessity of swallowing them in the living state.

Now these well-known and scientifically-named living organisms abound in the unfiltered waters of the Thames, Lea, and New River; but by the process of filtration to which the waters of the London water companies are now subjected, a very large proportion of them is removed; but usually by no means the whole. So that the number, variety, and size of the living organisms still contained in the

Fig. 4.



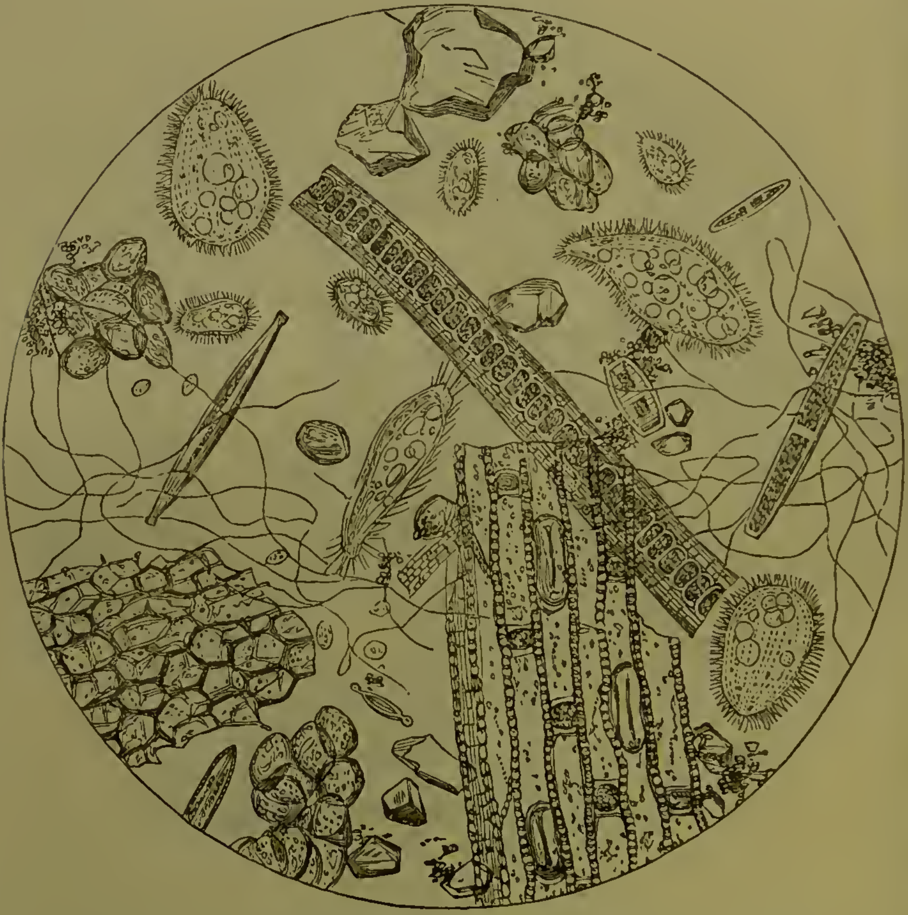
WEST MIDDLESEX COMPANY, 1851.

Exhibits the principal *animal* and *vegetable* productions then contained in the water of the WEST MIDDLESEX COMPANY. 220 diameters.

London waters after filtration, as delivered by the companies to the consumers, afford an excellent test of the efficiency or otherwise of the means of filtration adopted.

Any person, therefore, who fails to test by the microscope the efficiency of the filtration of any water known to contain such organisms, neglects to employ a very valuable means of ascertaining so important a fact.

Fig. 5.



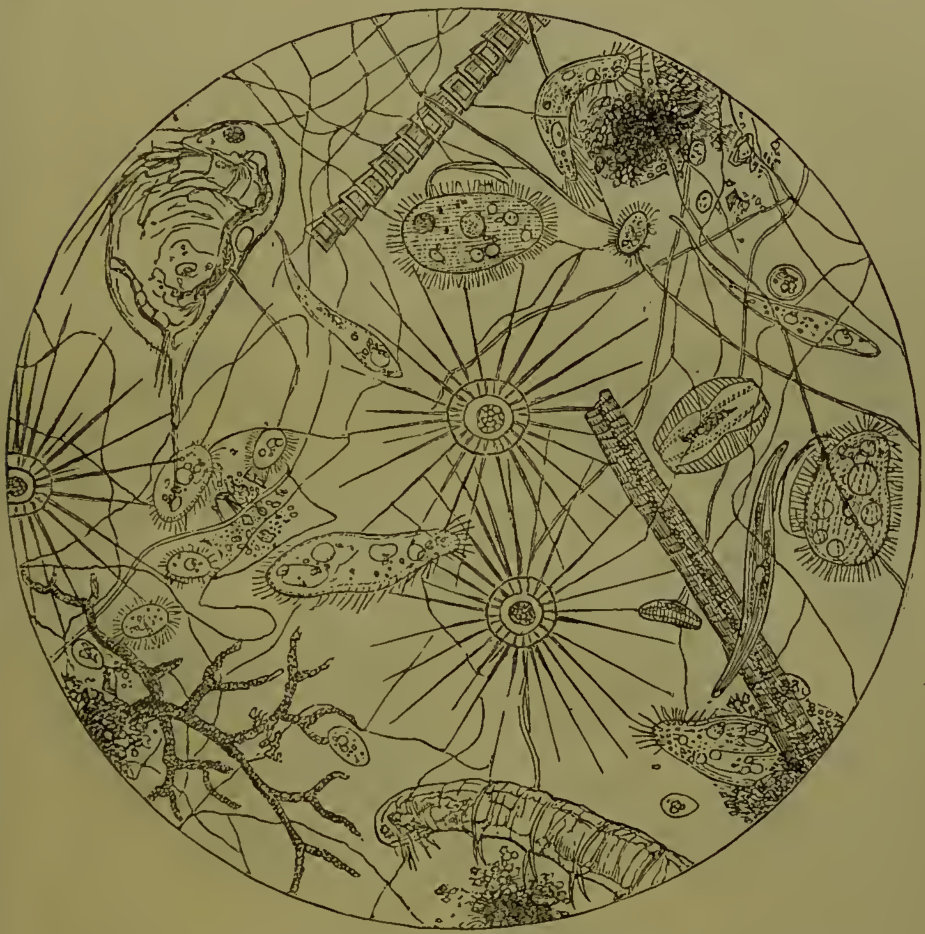
CHELSEA COMPANY, 1851.

Exhibits the chief *animal* and *vegetable* productions, including *husk of wheat*, present in the water of the CHELSEA COMPANY. 220 diameters.

So great is the effect of filtration in reducing the number of living productions in water, that we are even led to entertain the hope that a process of filtration may be devised and practised which will entirely, or almost free, our metropolitan drinking-waters from these highly objectionable inhabitants.

This result, it should be borne in mind, however, is as yet far from being realized.

Fig. 6.



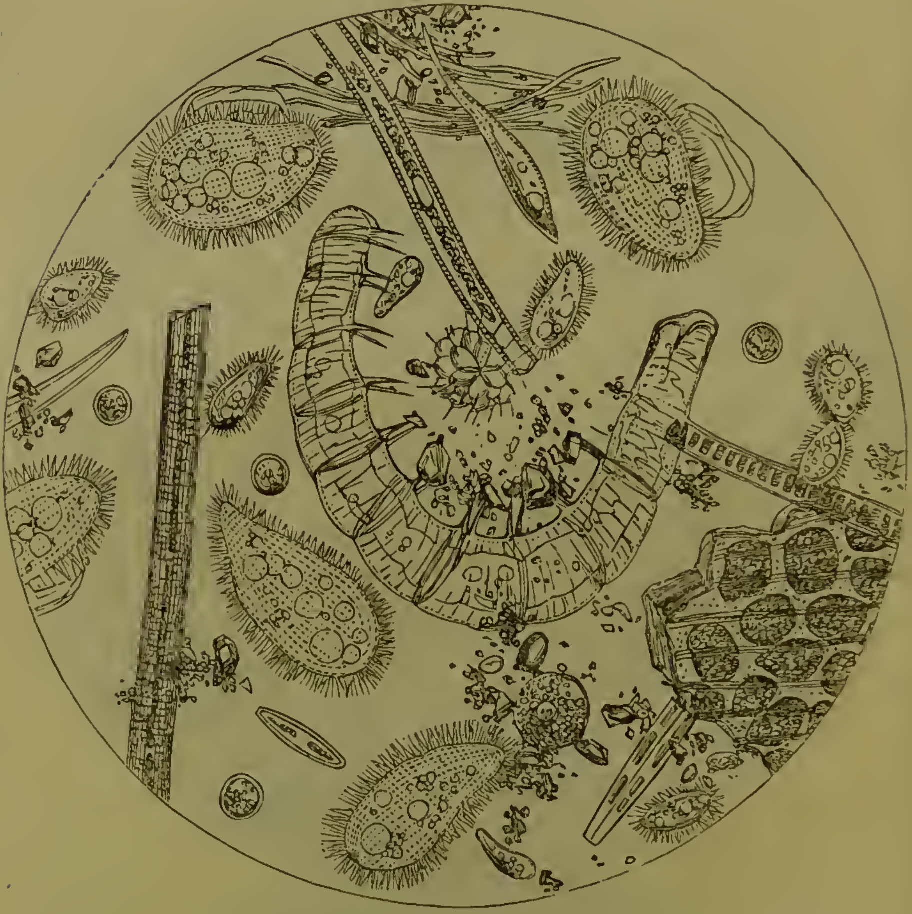
SOUTHWARK AND VAUXHALL COMPANY, 1851.

Exhibits the principal *animal* and *vegetable* productions then contained in the water as supplied by the SOUTHWARK AND VAUXHALL COMPANY. 220 diameters.

We now beg to call the special attention of the reader to the following remarks.

It is the belief of many medical men of high position and attainments that cholera and some other diseases owe their origin and diffusion to minute germs contained in water, and especially in the water of rivers. Well now, if the process of filtration is not efficient enough to remove all those more considerable and well-known creatures, which are named, described, and figured in scientific books, it certainly must fail to remove the minute cholera germs, &c.

Fig. 7.

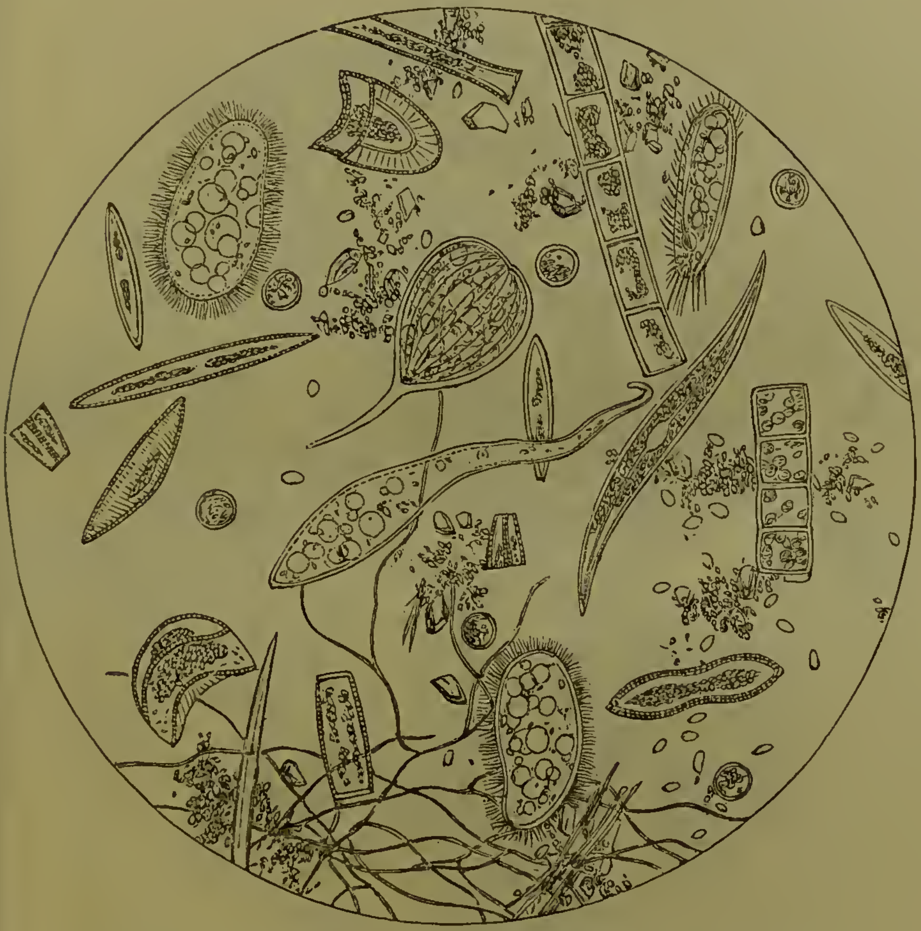


LAMBETH COMPANY, 1851.

Exhibits the organic matter, living and dead, especially the *Thames Paramecium* and husk of wheat, then contained in the water as supplied by the LAMBETH COMPANY. 220 diameters.

'Ah, but,' exclaims somebody, 'I don't believe in cholera germs.' Well, at all events, the fact is established to the satisfaction of most scientific men, that cholera is communicable through the medium of impure water, and that it has thus, more than once, been diffused by Thames water; and if the poison of that disease be not in the solid, it must be in the liquid form; and if the process of filtration now adopted is not sufficient to remove solid impurities—'living organisms'—it is certainly inadequate to the abstraction of the liquid poison.

Fig. 8.

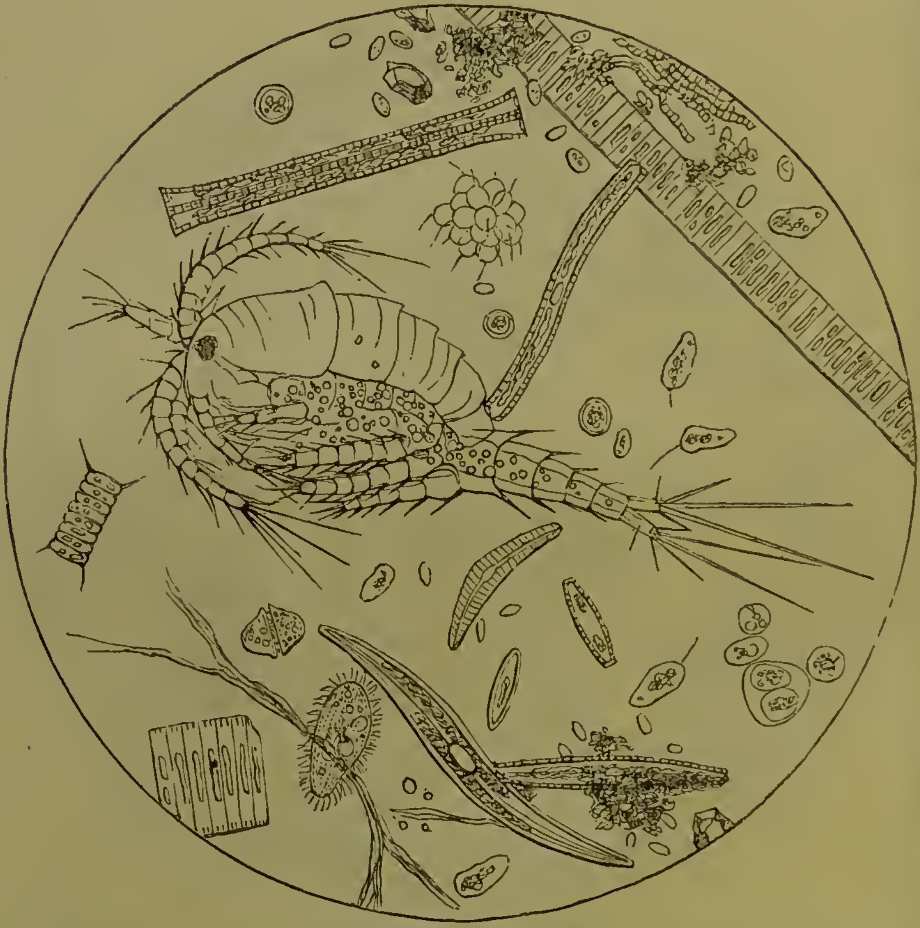


EAST LONDON COMPANY, 1851.

Sample of the water of the EAST LONDON COMPANY, showing the chief *animal* and *vegetable* productions then contained in it as supplied to the public. 220 diameters.

So, view the matter how we will, it is impossible to arrive at any other fair or safe conclusion than that the presence of these organisms in potable water is of very considerable importance. Bearing all these particulars in mind, we shall now be in a position to judge whether Dr. Frankland has exceeded his duty in instituting microsopical examinations of the metropolitan waters, and how far he is open to any

Fig. 9.

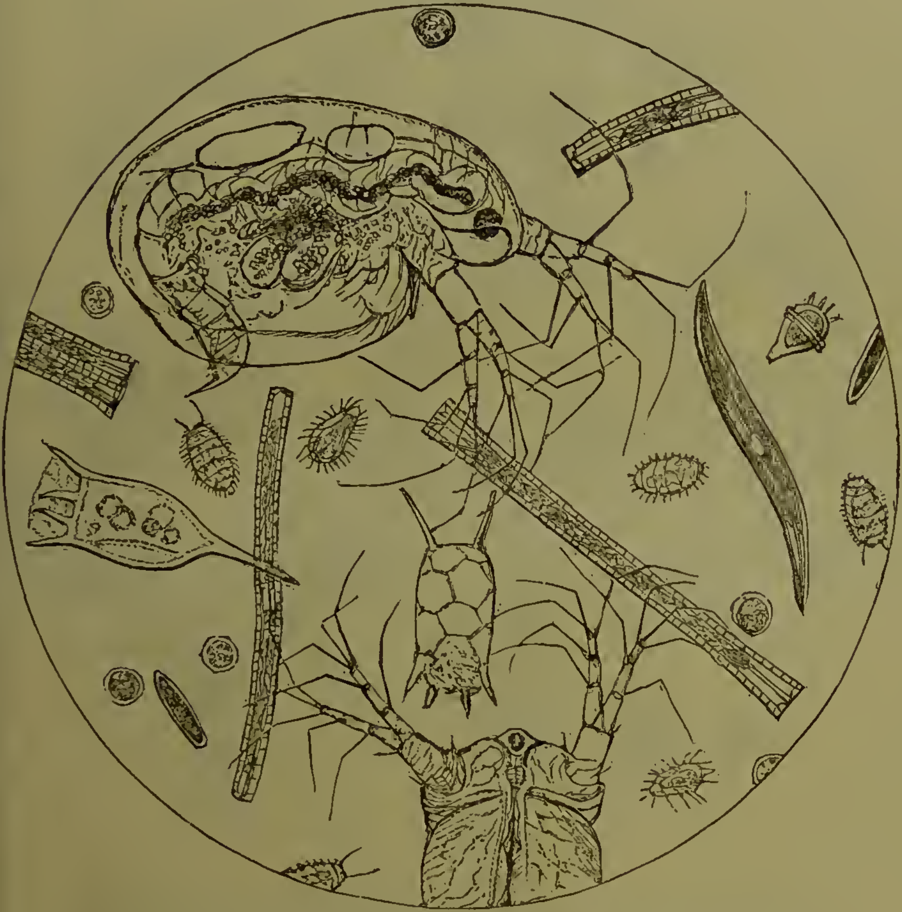


New River Company, 1851.

Sample of the water of the New River Company, showing the more remarkable *animal* and *vegetable* productions then contained in it as supplied to the consumers. 220 diameters.

just animadversion for publicly commenting on the presence of living organisms in such water. In our judgment, had he not done so, he would have fallen short of that plain duty which he has discharged, in the interests of the public, so ably and so courageously. That a charge of exaggeration should have been made under this head is the more to be regretted, since it emanates from those who from their position and duties should have been better informed than to have made it, and since their authority is calculated to mislead, and so do much injury to the public.

Fig. 10.



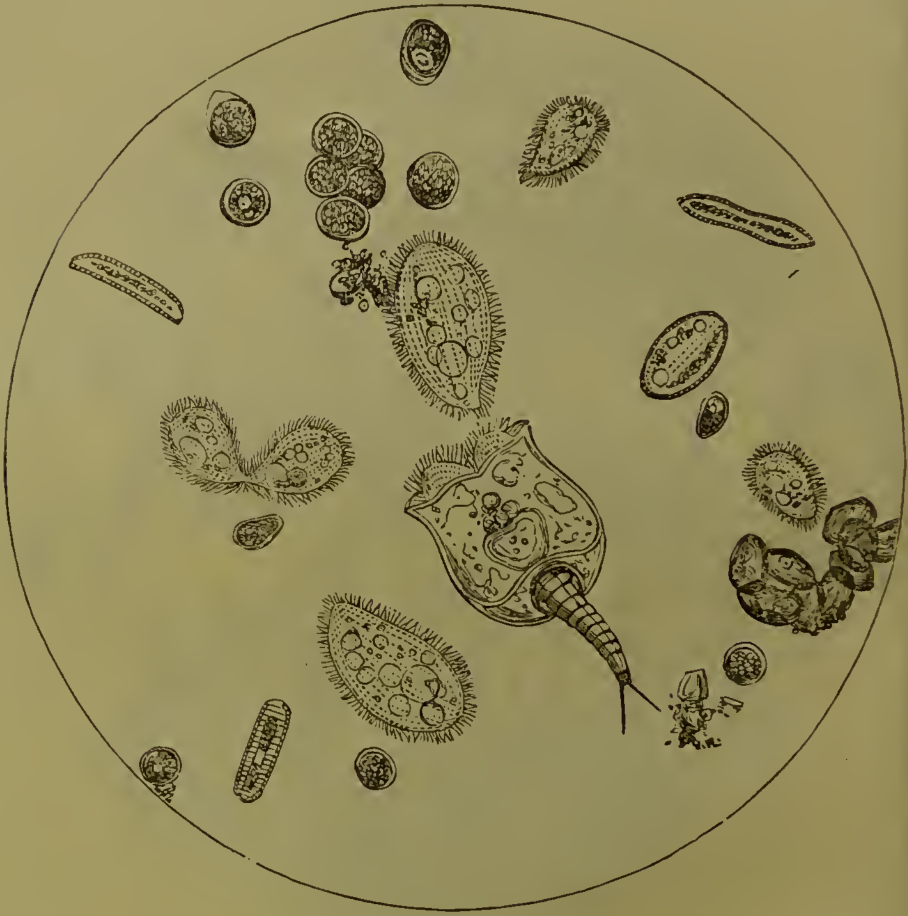
HAMPSTEAD COMPANY, 1851.

Sample of the water of the HAMPSTEAD COMPANY, exhibiting the principal *living* productions then detected in it as supplied by this Company. 220 diameters.

With a quotation from one of the reports of Major Bolton, the recently-appointed Water Examiner to the Board of Trade, and who is, we believe, an engineer, and not a chemist or microscopist, and with one or two brief comments thereon, we will bring these remarks to a conclusion:—

'I think it is to be regretted,' reports the Water Examiner, 'that such terms as "*living organisms*" and "*moving organisms*" have been used so frequently and indefinitely. It is well known that it is impossible altogether to get rid of the simplest forms of vegetable and animal life, which should be understood by such terms, even by the most perfect filtration,' &c.

Fig. 11.



Kent Company, 1851.

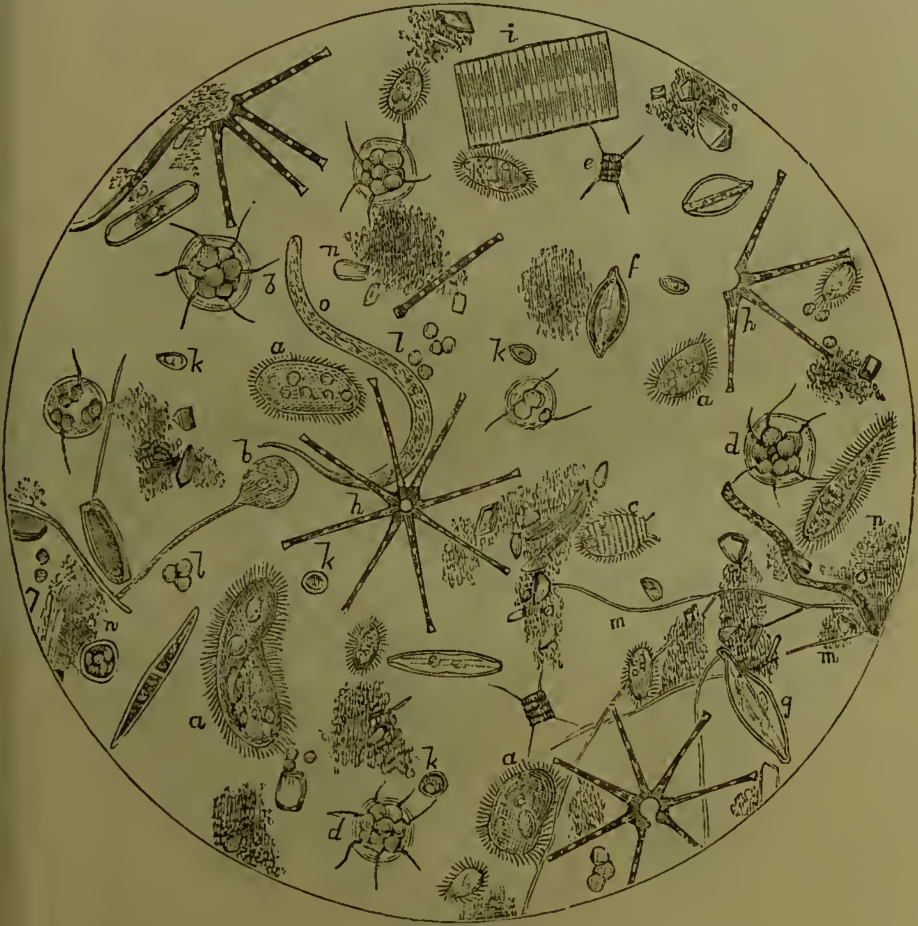
Sample of the water of the Kent Company, exhibiting the animalculæ in it then as supplied. 220 diameters.

There appears to us to be far more reason to regret that the Water

Examiner, to whom the public, from his official position, naturally look for sound advice and protection, should have penned such a paragraph.

WATER OF GRAND JUNCTION COMPANY (from Cistern), 1854.

Fig. 12.

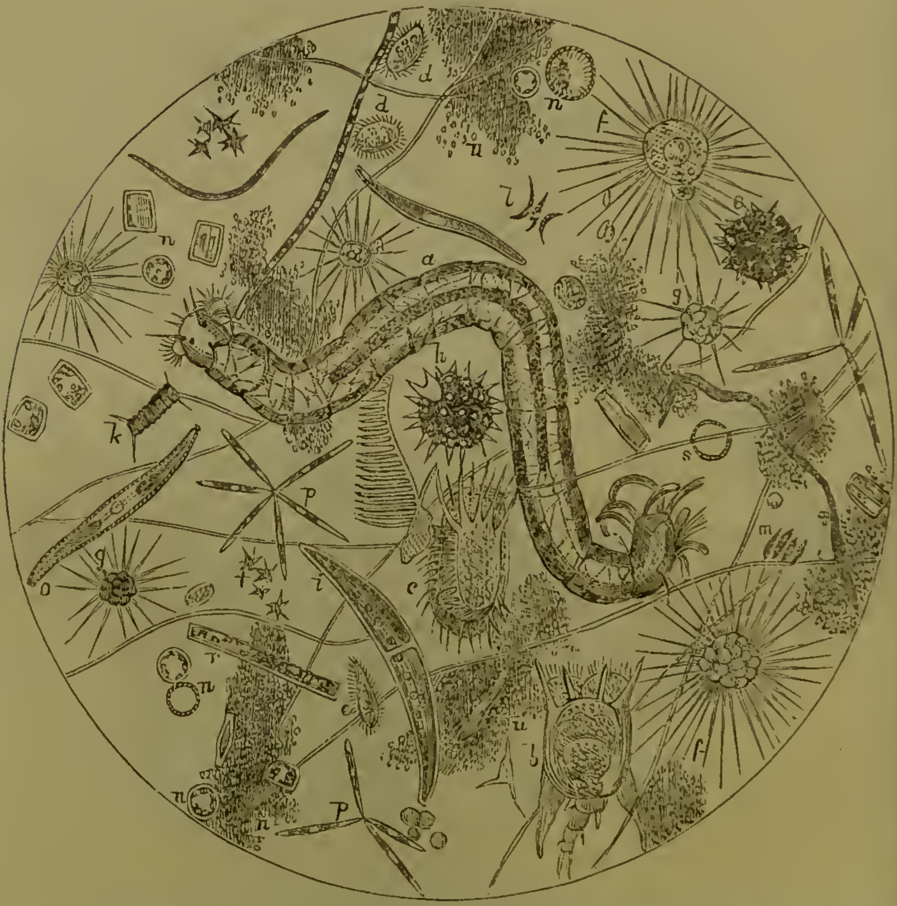


a, Paramæcia, 2 species ; *b*, Vorticella convallaria ; *c*, Coleps hirtus ; *d*, Pandorina Morum ; *e*, Scenedesmus quadricauda ; *f*, Navicula amphisbæna ; *g*, Navicula sphærophora ; *h*, Asterionella formosa ; *i*, Fragilaria capucina ; *k*, Brown active sporules ; *l*, Stationary green sporules ; *m*, Threads of slender fungus ; *n*, Organic and earthy matter ; *o*, Anguillula fluvialis. Magnified 220 diameters.

So far from too much attention having been paid to the presence of living productions in the Metropolitan waters, the reverse is the case ; and in most examinations of such waters by chemists their existence is usually altogether overlooked. We remind the Water Examiner that in the purer waters, those freest from dangerous contamination, such as those of springs and deep wells, these productions do not occur at

WATER OF SOUTHWARK AND VAUXHALL COMPANY (from Cistern), 1854.

Fig. 13.

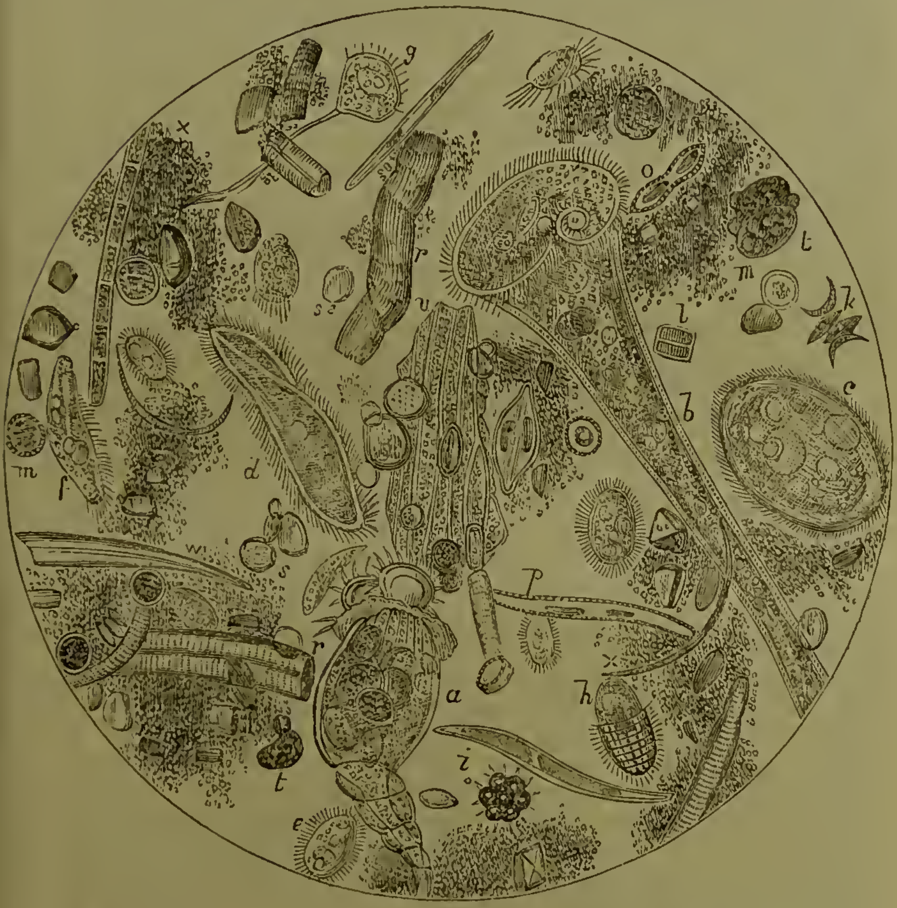


a, Blood-red Annelidæ ; *b*, Brachionus polyacanthus ; *c*, Euplotes charon ; *d*, Paramæcia ; *e*, Amphileptus ; *f*, Actinophrys Sol ; *g*, Actinophrys viridis ; *h*, Pediastrum Boryanum ; *i*, Closterium Lunula ; *k*, Scenedesmus quadricauda ; *l*, Scenedesmus acutus ; *m*, Scenedesmus obtusus ; *n*, Cyclotella operculata ; *o*, Nitzschia Sigma ; *p*, Synedra minutissima ; *r*, Melosira varians ; *s*, Threads of slender fungus ; *t*, Minute star-shaped bodies ; *u*, Organic and earthy matter. Magnified *a* 12, *h* 100, and the rest 220 diameters.

all ; that their presence is an evidence of impurity ; that filtration, as even now practised by the water companies, does succeed in removing by far the greater number of these living organisms; and so far from acknowledging that it is impossible altogether to get rid of them by the most perfect filtration, we believe that it is possible; and we are very certain that the numbers at present contained in the London waters might be still further very greatly reduced by a more efficient

WATER OF SOUTHWARK AND VAUXHALL COMPANY (from Service-pipe), 1854.

Fig. 14.



a, Brachionus; *b*, Stentor Mulleri; *c*, Bursaria; *d*, Paramæcium aurelia; *e*, Paramæcium sp.; *f*, Oxytricha; *g*, Vorticella convallaria; *h*, Coleps hirtus; *i*, Pediastrum Boryanum; *k*, Scenedesmus acutus; *l*, Melosira varians; *m*, Cyclotella operculata; *n*, Navicula amphisbæna; *o*, Cymatopleura Solea; *p*, Nitzschia Sigmoidea; *r*, Fragments of muscular fibre; *s*, Starch corpuscles of wheat; *t*, Starch; *u*, Husk of wheat; *w*, Hairs of wheat; *x*, Earthy and organic matter. Magnified 220 diameters.

method of filtration than that now practised. We presume that even the Water Examiner to the Board of Trade will not affirm that the method of filtration now adopted by the water companies is the most effective it is possible to devise.

Major Bolton seems very much concerned lest the public mind should become alarmed as to the state of the present water supply. There is, unfortunately, really no fear of any such result. It is well known that it is nearly impossible to rouse the public on such questions, and that they almost invariably display an apathy as marvellous as it is culpable.

It is some satisfaction to know that between the quality of the water wherewith the metropolis was supplied prior to the passing of the Act of 1852, and that which is now furnished to its millions of inhabitants, the greatest possible, indeed we may almost say the greatest conceivable, difference exists.

Before the date named, three of the companies drew their supplies of water from between the metropolitan bridges—namely, the Lambeth, the Southwark and Vauxhall, and the Chelsea Companies; while the West Middlesex Company took its water from the Thames at Hammersmith, and the Grand Junction Company from the river at Brentford. Now, prior to 1852, it was an easy thing to demonstrate, especially in the water of the Southwark and Vauxhall Company, and to a less extent in that of the Lambeth Company, as taken from the mains, the presence of the constituents of the *fæcal matter* derived from the sewers. Thus, by means of the microscope could be readily discovered, in a bottle of such water, the cells of *potato*, the *hairs* and *husk* of *wheat*, the broken *muscular fibre* of the meat consumed, as well as the filaments of the *cotton* plant, derived no doubt from *paper*. It has been our lot, not unfrequently, to demonstrate these matters in the water referred to, while in the pamphlet entitled 'A Microscopical Examination of the Water Supply of the Metropolis,' published in 1850, as well as elsewhere, we made known the fact and represented the constituents of fæcal matter thus detected in well-executed wood engravings: thus there is no room left for doubt or question. In addition to these matters present in the water of certain of the companies, they all swarmed with living productions, especially Annelidæ, Infusoriæ, Confervæ, Desmideæ, Diatomaceæ, not omitting to mention especially our old friends, Vibriones, which have been recently christened afresh Microzymes and Bacteria.

Well, then, at that period it was a common thing for some of the inhabitants of London to have returned to them, in the water of which they daily partook, a portion of their own excreta.

This horrible state of things has no doubt been rectified by the Act of 1852, whereby the Thames Companies were compelled to take their water from the river at Thames Ditton, subjecting it to comparatively efficient filtration.

Although we have on many occasions demonstrated the importance of the microscope in determining the nature of the organic constituents contained in potable waters, yet up to this time the use of that instrument in the examination of water continues to be greatly neglected. We well recollect that when called upon to give evidence before the Committee of the House of Commons on Water Supply, in 1851 (of which the late Sir James Graham was chairman), we produced abundant and overwhelming proofs that the waters with which London was then supplied, literally swarmed at all seasons with living productions, and this even as delivered to the consumers. We showed numerous drawings delineating some of the more prominent forms, we gave their scientific names, and described the classes or orders to which they severally belonged. We demonstrated also that some of these waters abounded in muscular fibre and other matters derived from the fæces, and yet we believe that this evidence failed to produce the slightest impression on the Committee, and the late Professor Brande, who was the next witness examined after ourselves, stated in the most confident manner that he did not believe that the waters of the Thames contained any such living productions as had been described.

Even in the inquiry relative to the Water Supply of the Metropolis, which was conducted before a Royal Commission so late as 1869, no evidence was taken as to the condition of the waters as revealed by the microscope, and hence the Commissioners were left without a very important means of judging the quality and condition of the then supply upon which they were deputed to form an authoritative opinion; and here it will be well to point out that rivers as sources for supply for drinking purposes are objectionable from the fact that they teem with thousands of different kinds of living productions; that they contain the ova of various parasites; that if there be any truth in the fungoid or animalcular theories of diseases, it is in rivers that the germs would be sure to be present, and through them that the diseases would be disseminated; and, lastly, that if epidemic diseases arise from special animal poisons, rivers afford the most effective channels for their diffusion.

In fact, a river may be likened to an open sewer, and it is indeed the readiest channel for the discharge of all the impurities of the districts through which the river flows.

The preceding observations have reference mainly to the smaller organic productions present in water, and which require the microscope for their satisfactory examination and identification, and which for the most part are free and unattached. But it must not be forgotten, that the larger productions contained in water, as *fish* and *aquatic vegetation*, exert likewise a very considerable effect in the purification of water, by removing from it a large quantity of the dissolved organic matter.

The illustrations given in this article of the many productions found in water used for drinking, and chiefly those of the Thames and Metropolitan Water Companies, were made some years since, and it must be clearly understood that they do not represent the condition of the waters now supplied by those companies, which has of late undergone very great improvement. Still the drawings in question possess much interest and value, for living organic productions, animal and vegetable, are still to be found in great abundance in many waters employed for all domestic purposes, including drinking.

MICROZYMES IN WATER.

Microzymes or Bacteria, the varieties of which are included under the general term 'Schizomycetes,' are other names for our familiar friends Vibriones, concerning the presence of which in potable water, in the renal excretion, and in the rice-water discharges of cholera, we many years ago treated in several publications relating to those subjects. Dr. Burdon Sanderson, by his recent experiments and observations, has invested these minute organisms with a new interest and importance, as we now propose to make apparent.

Microzymes, in their fully-formed state, consist of infinitely minute bodies, of an elongated or staff-like form, and with rounded and slightly enlarged ends. They appear to proceed from minute particles of matter imbedded in a transparent base or substance, often of a spheroidal form; they are coloured brown by iodine; they contain nitrogen in their composition, and are now believed by most observers to be of a vegetable nature allied to fungi, both morphologically and physiologically. They occur in liquids or moist air, but not dry air: in the first instance in a jelly-like basis, which also is presumed to be of an albuminoid character, but subsequently either diffused throughout the liquid or forming a scum on the surface; in which latter case Dr. Sanderson has observed that the rods stand vertically side by side. They, in some cases, as in Pasteur's solution, accompany and promote, if they are not the cause of, putrefactive decomposition, feeding on the nitrogen of the albuminoid material which the liquid contains, and when that is absent, even on the nitrogen of an ammoniacal salt, such as tartrate of ammonia.

From a great variety of experiments, Dr. Sanderson ascertained that microzymes are not developed in liquids which have been heated to a temperature of 356° F., or which have even been boiled, and this whether the liquids are exposed to the air or not, and provided also that any distilled water used has been boiled, and even the surfaces of the glass tubes and vessels employed have been heated, either by immersion in boiling water, or by subjection to the temperature named.[1] Now it is remarkable that, under the same circumstances which prevent the growth of microzymes, *fungi* appear, especially on the exposure of the liquids to air, and very abundantly in Pasteur's solution, which consists of a solution of sugar, tartrate of ammonia, and yeast-ash only. The reason of the necessity for boiling the distilled water and thoroughly drying, by heat, the surface of the glasses used, arises from the fact that the germs of the microzymes are to be found in many samples of such water, since they are not absolutely pure, and even in the moisture resting on the surface of glass. That ordinary air does not contain microzymes was proved by drawing, by means of an aspirator, a quantity of air through a boiled test solution, no microzymes appearing in the liquid after it had been kept for a considerable time; and it was further established that really pure distilled water does not develope microzymes.

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[1] 'The death point seems now to be very definitely fixed at about 110° C. = 230° F. for common septic bacteria.' (Dr. Sanderson, *in lit.*)

Now, the fact of the great impurity of many samples of distilled water, and also that microzymes or vibriones, fungi, and other animal and vegetable productions, are frequently developed in it, has long been known. The existence of microzymes in many impure waters was some years since pointed out by the writer in his *brochure* entitled 'A Microscopical Examination of the Waters supplied to the Metropolis,' and elsewhere, as also that they occurred in two states—free, and in gelatinous spheroidal masses.

Dr. Sanderson, therefore, from all his experiments, arrives at the conclusion that 'water is the primary source from which the germinal particles of bacteria are derived, whenever they seem to originate spontaneously in organic solutions;' and since their development depends on the presence, in impure water, of nitrogenous matter, it of course follows that, the greater the amount of this, the more abundantly are the microzymes developed when the water is added to Pasteur's test solution; and Dr. Sanderson proposes to judge of the extent of this kind of impurity of water by the degree of the *opalescence* produced by different waters operated upon in the same manner, as follows:—A small cylindrical glass, capable of holding ten cubic centimètres, is first heated to 395° F. This is then half-filled with boiling Pasteur's solution, and to this are added five drops of the water to be tested, the mouth of the glass being plugged with cotton wool. After each testing, the pipette used must be immersed for some minutes in boiling distilled water. If impure, after the lapse of from six to ten days, the upper part of the liquid will be observed to be opalescent, and, on examination with the microscope, microzymes will be detected. The tube in which the water is collected for examination must be prepared or superheated beforehand, both ends being hermetically closed before it leaves the flame of the blowpipe: thus prepared, it is filled by breaking off one end while it is under the water.

Dr. Sanderson terms the power of water to develope microzymes 'the zymotic property,' and measures it by their abundance, and the consequent degree of opacity to which their presence gives rise.

By the method above described, the waters of some of the London companies were tested, and all 'acted zymotically' in different degrees, filtration exercising 'no perceptible influence on the zymotic power of water.'

Further, Dr. Sanderson found that water obtained by the fusion of ice, which was so pure that it showed only a blue tint under the electric beam, was 'as zymotic as many other varieties of water which in the beam are seen to be full of light scattering particles.'

Lastly, it was ascertained that the microzymes, when thoroughly dried at a temperature of 104° F., and added to the test solution in the usual way, did not recover their vitality and give rise to any development of microzymes; the germinal power of which, when similarly tested, was also destroyed by ozone, permanganate of potash, carbolic acid, quinine, peroxide of hydrogen, and chlorine.

Experiments with blood, tissues, albumen, and urine showed that these are non-zymotic, while the results with milk, pus, and blister serum seem somewhat doubtful.

Such is a brief and, we trust, an intelligible exposition of Dr. Sanderson's researches and many experiments 'On the Origin and Distribution of Microzymes in Water.'[1] We will now proceed to make a few remarks on the results obtained.

As already stated, the fact of the presence of microzymes in impure water has long been known, but the observations in question show that either the microzymes themselves, or the germinal matter from which they proceed, are all but universally present in water, awaiting only the occurrence of circumstances favourable for their further development. That they most abound in waters of great impurity was also ascertained, and that from such water they should be freely produced when supplied with nitrogenous food, as is the case when Pasteur's solution is used, is but natural. The facts as to the non-conveyance of microzymes by dry air, and their destruction by thorough desiccation and by various re-agents, are interesting and important. Of the practical value of the microzyme test for determining the quality of a water we do not think very highly, and believe the method cannot be made safely to supersede, or be a substitute for, the usual qualitative and quantitative chemical examinations of water. No proof has been given that the microzymes are really capable of giving rise to contagious disease; they are contagious only in the sense that they infect the materials, if these are of a suitable nature to support them, with which they, through impure water, are brought into contact. The very fact of the universality of their presence in water is a reason for regarding these particular microzymes as harmless, so far as relates to the propagation of disease. Further, the propriety of the phrases 'zymotic power,' or 'zymotic property,' may be questioned, as applied to waters which either contain, or are capable of giving rise to microzymes, since the inference will be drawn by many that such waters possess the property of giving rise to 'zymotic diseases,' which has not been established.

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[1] Dr. Sanderson now uses, in place of Pasteur's solution, a suitable solution of soluble salts only, dispensing with the sugar and yeast ash, which contains phosphate of lime. The advantage of this is that sporules and tufts of fungi are not apt to appear in the liquid, and a clear in the place of a turbid solution is obtained, so that the commencement of the bacterium opalescence can be at once observed.

Dr. Sanderson, it should be noticed, however, does not regard any microzymes as contagious, excepting those which actually inhabit contagious liquids, and as regards these last he has pointed out the absence of any evidence that they are *causes* of disease.

STANDARD OF PURITY OF DRINKING WATER.

It would be a good and useful thing, for the public, and even the chemist and sanitarian, if a Standard of Purity could be fixed, whereby the quality—the wholesomeness, or otherwise—of waters used for drinking should be judged and determined. At present, the purity or impurity of a water is expressed by some such terms as the following—moderately good, good, very good; or, rather bad, bad, very bad; no two persons in using these expressions meaning exactly the same thing, having no rule or standard to guide them: thus a water which according to one chemist would be good, to another would be bad.

Now it is by no means an easy task to fix upon a standard of purity which all would be willing to accept, still it will be well to consider and discuss the question, in order to ascertain wherein the difficulties lie, and how near an approach can be made to such a standard as is now suggested.

Judged by its physical characters, a good drinking water should be entirely free from colour, taste, or smell; cool, well aërated and soft, bright, and entirely free from all deposit. It should be ever remembered, however, that the great majority of well waters in towns and cities, notwithstanding their coolness and brightness, are more or less polluted owing to the proximity of drains, cesspools, and sewers. Dr. Frankland defines the essential qualities of a good drinking water to be, 'first, coolness and aëration; secondly, freedom from organic matter of all kinds; thirdly, that it should never have been contaminated by sewage or manure in any form; and, finally, that it should be soft water, not over 5° of hardness.'

It is evident, from what has already been advanced, that a much wider range may be allowed to the mineral matter present in a water than to the organic. It is desirable, however, as a rule, that this should not exceed some 10 or 12 grains per gallon, on account of the hardness which excess of mineral matter usually entails. The water of the Thames companies contains about 16·50 grains of mineral matter to the gallon, and has an average hardness of 13·5°, reducible by boiling to 3·5°, and yet the comparative hardness of this water is often complained of, and it is certainly objectionable for cooking and washing purposes, although it is mostly of the temporary character.

Returning again to the published analyses of the waters of the London companies deriving their supply from the Thames, the quality of which is generally acknowledged to be below the requisite standard of purity, we find that they still contain on the average about 15-hundredths of a grain of albuminoid organic matter to the gallon, and consequently the amount of that constituent allowed should be less than that above-named; formerly the amount of albuminoid matter contained in these waters was very much greater.

Again, since ammonia, nitrous and nitric acids occur in very many waters, and since these afford indications of the extent of contamination to which a water is subject, the limits of these allowable should also be defined.

Now, in order to avoid fixing upon any impracticable standard, it will, in the next place, be desirable to quote the analyses given by the Rivers' Pollution Commission in 1871 of some of the purest waters hitherto supplied for the use of towns and cities.

In 100,000 *Parts.*

	Total solids.	Organic nitrogen.	Albuminoid matter.	Nitrogen as nitrites and nitrates.	Ammonia.	Total hardness.
Liverpool . . . . . Rivington Pike.	9·66	·029	·185	·000	·002	3·97
Manchester . . . . . Gathering grounds.	6·20	·009	·057	·025	·006	3·73
Oldham . . . . . Gathering ground.	12·80	·014	·089	·011	·004	6·96
Preston . . . . . Gathering ground.	12·44	·031	·198	·000	·006	8·94
Aldershot Camp . . . Gathering ground.	6·14	·048	·307	·000	·001	4·18
Lancaster . . . . . Gathering ground.	4·58	·022	·140	·000	·001	·87
Edinburgh . . . . . From Crawley Burn.	11·28	·031	·198	·000	·001	6·08
Whitehaven . . . . Ennisdale Lake.	2·16	·017	·108	·000	·001	1·45
Keswick . . . . . From Skiddaw.	4·34	·024	·153	·000	·001	3·37
Dublin . . . . . River Varty.	6·34	·024	·153	·000	·001	2·97

These results are remarkable and for the most part very satisfactory, for they show that not only are waters of a high degree of purity attainable, but that large towns and cities are already supplied with them—the purity extending even to the mineral matter, rendering these waters not merely fitted for drinking, but also for all domestic purposes, as cooking and washing. The albuminoid organic matter is, however, in most of these waters still too high; but we must remember that Frankland's mode of analysis furnishes higher results than does Wanklyn's method.

Taking into consideration the several data above given, we would fix the following as 'The Standard of Purity' at which, in the supply of water for drinking purposes, it is desirable to aim :—

Per 100,000 *Grains.*

Mineral matter.	Free ammonia.	Albuminoid matter.	Nitric and nitrous acid.	Hardness, temporary.	Hardness, permanent.
14–17 parts	0·005	0·10	0·35	10	2

The following analyses of a few samples of bad water are in striking contrast with the standard above given :—

Samples of Impure Water recently Analysed in the Laboratory of the Author.

Total solids . .	84·6	104·8	129·9	68·0
Total hardness .	41·6	59·2	68·0	35·2
Chlorine . . .	6·93	15·618	28·14	12·340
Free ammonia .	1·288	0·023	0·014	0·0091
Albuminoid ditto .	0·028	0·01	0·0081	0·0131
Nitric acid . .	—	—	—	9·072

Total solids . .	126·0	108·9	170·6	95·5	144·8
Total hardness .	26·7	53·4	29·2	34·96	30·6
Chlorine . .	12·0	0·776	23·70	15·23	11·862
Free ammonia	0·003	0·046	0·006	0·0069	0·875
Albuminoid ditto	0·013	0·005	0·012	0·0219	0·0098
Nitric acid .	10·991	8·233	0·186	5·965	5·092

The number of illustrations of bad waters might have been further extended, but their multiplication would serve no useful purpose. In nearly all cases in which there is much nitric acid, the chlorine is also greatly increased.

It must be clearly understood, however, that it is impossible in many cases to judge of the quality of a water by simply regarding only one result of an analysis, but the whole must be taken into consideration, and the one balanced against the other. Thus a water may contain a large quantity of nitric acid, but only a minute quantity of free ammonia and albuminoid matter, and such a water would have to be regarded as pure and fit for drinking purposes. Again, another water may contain a considerable excess of mineral matter as well as nitric acid, and yet be a very pure water as respects the organic constituents, and hence it might be used for drinking purposes with safety, although its hardness would render it less fit for domestic use than a softer water. But we now call the reader's special attention to what follows. Some few instances are on record in which waters with but little organic or mineral impurity have produced epidemic disease; and had a chemical standard been followed, the water would have been pronounced pure and wholesome. It is in such cases as these that so far chemistry fails us; but these are for the most part quite exceptional, and such cases are to be explained by the contamination of the water with the special poisons of cholera and typhoid, which are capable of producing these diseases, even when the minutest quantities of the poisons find an entrance into the system. Now this last fact is one which shows how necessary it is to avoid as far as possible the use of all waters, like those of rivers, specially liable to contaminations of so many kinds, and particularly excremental impurity and the discharges of persons attacked with epidemic diseases.

The celebrated surgeon, Sir W. Fergusson, in his address at a meeting of the British Medical Association, recently held in London, told the doctors, sanitarians, and chemists, that their opinions about water were all wrong; that in the case of a water supply quantity is of far more importance than quality; that we ought not to object to dead or even living organic matter in potable water 'in the shape of a few fleas.' Upon what grounds, think you, has the learned and respected professor arrived at this startling conclusion? Firstly, because a great deal of the water met with is, in its untreated condition, more or less contaminated, and hence the difficulty of obtaining pure water; but Sir William fails to point out why it is so much of the water met with is thus contaminated, and to show that this contamination is due to the polluting influences of man himself through his manufactures and his sewage. He ignores the wise old maxim: 'Cleanliness is next to godliness.'

Secondly, he bases his opinion on the fact that the soups we partake of all contain large quantities of organic matter, the dread of the water chemist; and that as soon as ever the purest water is swallowed and brought into contact with the human body, it immediately becomes contaminated with this dreaded animal matter.

In making these remarks Sir William proves how dangerous and difficult a thing it is for one not really conversant with the subject of which he treats to handle it aright. By them he shows that he has totally misunderstood the whole point and meaning of the question. It has never been contended by chemists that the organic matters determined by them in water constitute the injurious constituents, the *materies morbi* in water; they simply regard the quantities in which they are present, combined with the circumstances under which they occur, as the measures of the impurity to which they are exposed, and as indicating the degree of liability of any water to become contaminated with the special poisons of cholera, typhoid fever, or other disease. Viewed in this light, the exact determination by chemists of the impurities of water, of the albuminoid organic matter, &c., becomes a question of the highest importance, since it is the means of showing not only where danger of infection exists, but also where means of prevention should be specially adopted. Thus viewed it is, and will continue to be, the bounden duty of the physician, the sanitarian, and the chemist, to use their utmost endeavours to secure for the public an ample supply of the purest water which can by every reasonable means be obtained.

Supply of Water per head.

The supply of water for a town should be, according to the best authorities, about 25 gallons per head per day for all purposes, but great variations exist in the actual quantity supplied in different towns and cities. Thus, according to Mr. Bragg, the quantity per head is in Norwich 12, and in Derby 14 gallons, while in Edinburgh, according to Parkes, it is 35, in Southampton 35, and in Glasgow 50 gallons per head. Parkes estimates the quantity necessary for personal and domestic use, without baths, at 12 gallons per head per day as a minimum supply, and with baths 16 gallons; but this makes no allowance for water-closets or for waste.

It has not yet been determined what quantity should be allowed for closets, but Parkes states that six gallons per day per head should probably be allowed, he pointing out that in this particular instance false economy in the use of water is most undesirable. We thus account for 22 of the 25 gallons above alluded to; but since allowance must be made for waste and for an extra supply for closets, the estimate of 25 gallons seems a fair and reasonable one. It must be remembered, also, that a less amount than the above would scarcely suffice to effect the necessary cleansing of the sewers, an object of such essential importance.

IMPURE WATER A SOURCE OF DISEASE.

It has been fully established that impure water is a fruitful cause of disease, and a great body of evidence to this effect has already been obtained, and it is, moreover, daily increasing; disease being occasioned, so far as is known, by the organic matters which the water contains.

Of the nature and condition of these matters but little that is precise is known; the most hurtful, there is reason to believe, are those which are in suspension, and especially when derived from recent sewage and fœcal matter. At all events, this would appear to be the case, from the fact that many of the waters which have been proved to be productive of disease have been found to be more or less turbid, and to contain sedimentary matters. At the same time, however, those which are held in solution are probably also hurtful; for disease is frequently traced to the use of waters which are perfectly bright and clear, and which contain no appreciable sediment. Again, some of the fatty acids, mostly in the combined state, derived from the decomposition of organic matter, are also believed to exert injurious effects, as *formic, acetic, propionic, butyric,* and *caproic* acids, and particularly *butyric,* and in a less degree *nitrous* and *nitric* acids. These last acids, even in the combined state, exert, as will be shown, a powerful action on lead and other metals with which they are brought into contact, and they are also strongly diuretic. As to the much-debated question of the production of disease by specific germs, nothing positive has as yet been established. There is no reason, as far as we are aware, to believe that the ordinary living productions contained in some drinking waters, especially those derived from rivers, are themselves productive of disease, excepting only the ova of various intestinal worms and other entozoa which are thus introduced into the stomach and intestines, where they become developed. Such productions are rather to be regarded as evidences of the contamination of the water in which they are present, and to the purification of which they contribute by their development and growth.

According to some authorities, the presence of a certain amount of lime, chiefly in the form of carbonate, in drinking water, is necessary to health, it furnishing the lime which enters into the composition of the osseous system. This view we have already stated we believe to be entirely erroneous; partly since almost all the articles of food consumed, especially vegetables, meat, milk, &c., contain that base in quantities far exceeding the amount met with in most potable waters. While, therefore, there is no reason to believe that lime is an essential constituent of water, on the other hand there does not appear to be any evidence to show that when the quantity present is but small it exerts any injurious effects; and the same may be said of the chloride of sodium usually met with in water. The chlorides of calcium and magnesium, and the sulphates of the same bases, if in large amount, would doubtless tend to render a water unwholesome in many cases, in consequence of the aperient and other properties possessed by these salts. Again, iron in water, in any but the smallest amount, would be calculated to produce evil results with many, as headache, constipation, &c.

It has been very frequently affirmed that the use of hard calcareous waters is productive of *stone*; but there is still a great want of any conclusive evidence establishing this point. It is, indeed, well known that calculous affections are especially prevalent in many districts, but it has not been proved that the prevalence is due to the character of the water supply.

The following disorders and diseases have all of them been produced by impure water—namely, *dyspepsia, diarrhœa, dysentery, cholera, typhoid fever, scarlet fever, malarious fevers,* and *ague.* In fact, one or other of the above diseases is always more or less prevalent throughout the country, due to the consumption of impure and contaminated water. Indeed, a whole volume might be written on this subject, but to enlarge upon it would extend this article beyond the limits at our disposal.

Affections of the stomach, dyspepsia.—It will be seen that the effects of impure water are mainly exerted, as might have been expected, upon the mucous membrane of the stomach and intestines, with which the water is brought into contact. Parkes states that 'symptoms, which may be referred to the convenient term dyspepsia, and which consist in some loss of appetite, vague uneasiness or actual pain at the epigastrium, and a slight nausea and constipation, with occasional diarrhœa, are caused by water containing a large quantity of calcium chloride and sulphate, and the magnesian salts. Dr. Sutherland found the hard water of the red sandstone rocks, which was formerly much used in Liverpool, to have a decided effect in producing constipation, lessening the secretions, and causing visceral obstructions; and in Glasgow the substitution of soft for hard water lessened, according to Dr. Leech, the prevalence of dyspeptic complaints.' . . . 'The exact amount which will produce these symptoms has not been determined, but water containing more than eight grains of these substances, individually or collectively, appears to be injurious to many persons.'

Diarrhœa.—Diarrhœa may be produced by the irritation of mineral substances *mechanically suspended* in the water, as *clay* and *marl*, as well as by *suspended* and *dissolved organic matters*, especially those of an animal nature, as *sewage* and *fæcal matter*. 'In cases in which the water is largely contaminated with suspended sewage, it is important to observe that the symptoms are often markedly choleraic (purging, vomiting, cramps, and even some loss of heat).' The drinking of water impregnated with sulphuretted hydrgen and sewer gases will likewise give rise to diarrhœa.

It has already been noticed that the *dissolved mineral matters* sometimes, even when contained in water in small amount, give rise to various symptoms of dyspepsia, but they are also sometimes the cause of diarrhœa, especially those waters which contain any considerable amounts of the *sulphates of lime*, *magnesia*, and *soda*. It is stated also that diarrhœa is caused by waters containing either the *nitrate* or the *butyrate of lime*. There seems to be a dearth of information as to the special effects of waters which, otherwise pure, contain a considerable amount of *carbonate of lime*. It is further well known that brackish water, the chief constituent of which is *chloride of sodium*, will also frequently give rise to diarrhœa.

Dysentery.—Another disease unquestionably produced by impure water is dysentery, and there are many outbreaks of that complaint which have been traced to the use of highly contaminated waters. It has been proved that when the evacuations of those labouring under dysentery make their way into drinking water, it is rendered capable of propagating the disease, as is also the case with typhoid fever and cholera.

Cholera.—The evidence which has now been accumulated appears to thoroughly establish the fact of the propagation of cholera by means of drinking water containing cholera-evacuations, but many are of opinion that the consumption of impure water of any kind predisposes to the disease, either by causing diarrhœa or by introducing into the alimentary canal 'organic matter which may be thrown into special chemical changes by a small quantity of cholera poison which has been introduced with air or food and swallowed.' (Parkes.) The latter supposition seems to us scarcely probable, since if the cholera poison had already found its way into the intestines, where of course it would increase and multiply, nothing more would appear to be required for the full effects of the disease to be produced.

Typhoid fever.—Another of the diseases now ascertained to be communicable by impure water, as well as air, is typhoid fever. Dr. Parkes draws attention to the fact that the incubative period of the disease is much shorter in cases of typhoid resulting from the drinking of specially contaminated water than when the disease is propagated through the medium of the air. In the latter case from 8 to 14 days may elapse before the early *malaise* comes on, while in the former the symptoms sometimes become marked in two or three days. It has not yet been determined as to whether typhoid fever may be propagated otherwise than through the medium of typhoid evacuations introduced into the system either through water or air. 'Whether or not a special putrefactive change going on in these evacuations can be communicated to other organic matter out of the body is not certain.' (Parkes.)

Scarlet fever.—Some evidence has been obtained by Dr. Wallace at Wood Sutton, which goes to show that scarlet fever may also be propagated by water, but we are left in doubt as to whether the *materies morbi* was derived from the fæcal evacuations or from the skin of those suffering from the disease.

Malarious fevers, including ague.—Of the production of these fevers by impure water there would appear to be no room for doubt, but the evidence seems to point strongly to the vegetable rather than to the animal nature of the immediate cause, the waters giving rise to the disease coming from marshes. Several very striking instances have been recorded of the prevalence of ague in localities in which the drinking water was obtained from marshy districts, and in which the disease immediately disappeared on this source of supply being abandoned and water being obtained from wells.

'One very important circumstance is the rapidity of development of the malarious disease and its fatality when introduced in water. It is the same thing as in the case of diarrhœa and dysentery. Either the fever-making cause must be in larger quantity in the water, or, what is equally probable, must be more readily taken up into the circulation and carried to the spleen, than when the cause enters by the lungs.' (Parkes.)

Although no conclusive evidence has as yet been given of the mode of propagation of *yellow fever*, yet it is not unlikely that this disease, as also some others, and possibly amongst the number *erysipelas*, may frequently owe their diffusion to impure and specially contaminated water.

Goître.—Another disease of a totally different character, undoubtedly produced by impure water, is goître. The evidence of its being so occasioned is unusually strong and convincing, and this cause, in some instances, it is stated, will give rise to the production and development of goître in as short a time as from 8 to 10 days, while in some districts in France and Italy goitre may be produced at will by the drinking of certain waters.

Considerable difference of opinion exists as to the nature of the constituents of water which give rise to goître, but there is much reason to believe that the lime and magnesian salts play an important part, although, in some instances, the latter salts are absent. Dr. M'Clellan has shown that no less than 33 per cent. of the population in the Kumaon district, who use water from the limestone rocks, suffer from goître and 3·1 from cretinism, while those affected in districts in which the water supply is derived from the granite and gneiss and the clay slate amount to less than 1 per cent., there being no cases in the districts supplied with water from the mica slate, hornblende, and green sandstone. M. Saint-Lager, however, denies that there is any connection between the hardness of water and goître, and attributes it either to iron pyrites (sulphide of iron) or to some other metallic sulphide, and he accounts for Dr. M'Clellan's results by the statement that the water in Kumaon had passed through certain metalliferous strata.

While, therefore, there is considerable difference of opinion as to the nature of the constituents of water which give rise to goître, it would appear that the question is one which might be definitely determined by a properly conducted chemical investigation.

Entozoa.—Lastly, it has been abundantly established that several kinds of entozoa, either as ova or embryos, find an entrance into the body through the drinking-water consumed. This is certainly the case with *Bothrio cephalus latus*, *Ascaris lumbricoides*, and most probably also the *Dochmius duodenalis* and *Filaria dracunculus*.

Lead.—Another contamination or impurity of water is with that highly poisonous metal, *lead*, which, in some cases, becomes dissolved to such an extent as to produce symptoms of *lead poisoning*.

It appears from evidence on record that as little as $\frac{1}{100}$ grain of lead in a gallon of water has given rise to lead poisoning and paralysis. In the well-known case of poisoning which occurred in the family of Louis Philippe, at Claremont, the amount of lead found was $\frac{1}{10}$ grain in a gallon.

The water with which Edinburgh is supplied contains, according to Parkes, the $\frac{1}{140}$th of a grain per gallon, a quantity which has not been found to be hurtful; illness has also resulted from the consumption of waters containing other metals, as *iron, zinc, copper* and *arsenic.*

ACTION OF WATER ON LEAD AND ZINC.

A great deal has been said and written on the important subject of the action of water on the leaden pipes through which it is conducted to the consumer, and on the cisterns in which it is stored. Although the statements made are somewhat contradictory, yet the actual facts may now be said to be well ascertained and established.

For many years it was universally believed that soft waters acted most on lead and hard least, but, as will be presently shown, this statement is not corroborated by further and more exact observations and experiments, the action of soft waters on lead being due not to the water itself, but to the oxygen and other substances with which it is more or less impregnated.

First. The *gases* and *salts* which most attack lead are *oxygen, nitrous* and *nitric acids,* whether free or combined; all the *chlorides*; *caustic lime,* as contained in mortar, &c., soluble compounds being formed with all these.

Carbonic acid likewise attacks lead, but the resulting compound is insoluble unless in the presence of a considerable excess of carbonic acid. Thus a film or coating is frequently found on the surface of lead cisterns and pipes, consisting usually of a basic carbonate of lead, with two molecules of carbonate of lead and one molecule of hydrated oxide. But according to Mr. Lauder Lindsay, this coating has frequently a more complex composition, and consists of the carbonates, phosphates, and sulphates of lime and magnesia, with some chloride of lead. This film or crust is liable to become diffused through the water when it is agitated, and in this way it may be introduced into the system; but it is said that the coating thus formed on the surface of lead exerts a protective effect by retarding or preventing the action of the other substances on the metal.

According to Medlock, *nitrite of ammonia* exerts the greatest influence on lead, the nitrite of that metal being formed. The nitrite of ammonium being a volatile salt, is found in most distilled waters obtained from an impure source.

The salts which exert the least action on lead are *carbonate, sulphate,* and, according to Frankland, especially *phosphate of lime*; also in a less degree the corresponding salts of *magnesia* and the *alkaline phosphates.*

Second. *Organic substances* affect lead powerfully, and the *organic acids* generally, as those derived from fruit, beer, milk, cider, &c.

Third. Another way in which lead becomes dissolved is by *galvanic action,* as when lead comes into contact with iron, zinc, or tin. Zinc pipes often contain considerable quantities of lead, and hence, without it being suspected, water has frequently been found to contain that metal.

In the same way, water sometimes becomes contaminated with a variety of other metals, but particularly with the following—namely, *iron, zinc, copper*, and *arsenic*. It is said that rain-water collected from a zinc roof is not unfrequently found to be sufficiently contaminated with *zinc* to prove injurious.

EFFECT OF GEOLOGICAL FORMATION ON THE COMPOSITION OF WATER.

As we have seen, all water dissolves during its descent through the soil different mineral constituents. It is evident that, according to the geological formation through which the water passes, its dissolved constituents will vary, and frequently it is possible to say what substances and salts are most likely to be found in a water derived from a certain formation. The following are the characters of the waters obtained from different formations, epitomised from Dr. Parkes' 'Practical Hygiene.'

1. *Waters from granitic, metamorphic, trap rock and clay slate.*—The total solids are usually very low, seldom exceeding 6 grains per gallon. They consist of carbonate and chloride of sodium, with little lime and magnesia. The quantity of organic matter is very small.

2. *Millstone grit and hard oolite waters.*—These waters resemble the preceding; they are very pure, and contain sulphate and carbonate of lime, and magnesia with traces of iron, the solids seldom exceeding 8 grains per gallon.

3. *Soft sand rock waters.*—The waters derived from these sources are, as a rule, impure, and usually contain much chloride, sulphate, and carbonate of sodium, with little lime and magnesia. The total solids range from 30 to 80 grains per gallon, the organic matter being sometimes as much as 8 grains per gallon and even more. Occasionally these waters are pure and soft.

4. *Loose sand and gravel waters.*—The composition is extremely variable, the total solids varying as much as from 4 to 70 grains per gallon. The reaction is frequently alkaline, and the organic matter somewhat high. The Farnham waters, and some of those from the green sand, are very pure, the total solids not exceeding 8 grains.

5. *Lias clay waters* contain mostly very large quantities of mineral matter, from 100 to over 200 grains per gallon.

6. *Chalk waters* are usually pure, containing in solution from 7 to 20 grains of carbonate of lime. The permanent hardness is very small, as is also the amount of organic matters present.

7. *The limestone and magnesian limestone waters* resemble the latter in many respects, but contain more magnesia and sulphate of

lime. The permanent hardness is greater than in the preceding. Organic matter usually in small amount.

8. The *selenitic waters* are rich in sulphate of lime, and consequently in permanent hardness, which renders them unwholesome waters, liable to produce dyspepsia and constipation, alternating with diarrhœa.

9. *Clay waters* are chiefly surface waters containing but few dissolved constituents, but much suspended matter.

10. *Alluvial waters.*—The amount of total solids is variable, from 20 to 120 grains. The organic matter is high and often derived from admixture and contamination with sewage; hence these waters are for the most part impure.

11. *Surface and subsoil waters* of course vary greatly in composition, but are mostly very impure, and should not be used for drinking purposes. Butyric acid, in union with lime, is in some cases found in these waters.

12. *Marsh water* is mostly very rich in vegetable organic matter, containing from 12 to even 50 grains per gallon, and is often of a strongly yellow colour. Suspended organic matter is also common. It is highly impure, and frequently gives rise to malarious fevers.

13. *Water from graveyards.*—These waters abound in nitrite and nitrate of ammonia and lime, with sometimes the fatty acids and much organic matter.

THE ANALYSIS OF WATER.

Collection of Samples.

In collecting samples of water for analysis, attention is most particularly requested to the following points.

The bottles must be stoppered. Those known as Winchester quarts are most convenient, and can be obtained of any chemist and druggist.

They must be most thoroughly and effectually cleaned. Shot must not be used for this purpose. They should be rinsed with the water that is being collected at least three times before being filled, and should then be filled *nearly*, but not quite, up to the stopper.

The following quantities are required:—For a full analysis of a water supply—well-water or a river-water, two Winchester quarts; for a partial analysis, one will be sufficient; for sewage, one Winchester quart.

In collecting from a water supply, the sample should be obtained, if possible, directly from the main. If taken from the house-service tap, it should be allowed to run freely for one or two minutes before bottling.

In obtaining samples from a river, the bottles should be plunged into the water as far as possible from the bank (great care being used not to disturb the mud), their mouths being kept well below the surface until they are filled.

In collecting samples of the water of rivers, especially those into which sewage flows, it must be remembered that the quality and condition will be found to vary according to the state of the tide, and also to the seasons of the year. These differences are well exemplified in the case of Thames water, the amount of suspended and organic impurities being by far the greatest in this at low water, and also in winter, because at that season of the year the organic matter is washed out by the rains and floods from the lands bordering on the river, as well as for the further reason, that during the winter the purification effected by oxidation and by the growth of aquatic plants is far less active than in the warm weather of summer.

Sewage should, if possible, be collected thus:—A common pint potful should be taken as often as possible during the day, and poured into a large clean jar; at the end of the day this should be thoroughly well shaken, and the sample bottle filled from it. A fair daily average of the sewage is thus obtained.

In cases requiring extreme accuracy the daily flow of the sewage should be gauged, and arrangements made for securing continuous daily samples.

Microscopical examination of water.—The same quantities of water will serve for the microscopical examination as well as the chemical analysis; both the clear water and any sediment which may be found in it after it has stood at rest for some hours, should be examined with the microscope in the usual manner on slips of glass, with thin glass covers over the preparation. For the clear water, cells may be used in order to obtain a greater depth. The sediment may be best obtained from the bottom of the bottle by means of a pipette, one or two drops only being then removed for examination.

Frequently, the physical characters of a water and simple qualitative tests are sufficient to enable one to judge of its quality.

I. *Physical characters and appearance.*—The *colour* and *clearness* of a water are first ascertained by observing it in a layer 2 or 3 feet in thickness, by filling a wide glass tube, closed at one end, with the water to be examined, and by looking in the direction of the axis through the stratum of water. In this way even the minutest tinge or colorisation will be readily seen, and the slightest turbidity will be perceptible. Pure waters are nearly always perfectly clear and colourless, while contaminated waters, especially if the contamination be recent, show frequently a strongly yellowish colour. For comparison a second tube may be filled with distilled water, or a water of known purity. A water containing much suspended matter is usually unfit for drinking purposes.

The *smell* of the water may either be observed after violently shaking a pint or more of the water in a flask to liberate the dissolved gases, or after gently heating the sample. Good waters never emit any smell, whilst samples exhibiting any foul odour are to be rejected as unfit for use.

Next, *taste* some of the water, if possible freshly drawn from the well. Large quantities of dissolved mineral constituents, especially chloride of sodium or common salt and iron, are readily detected. But it must be borne in mind that not unfrequently highly impure waters appear to possess a most agreeable and refreshing taste, whilst, as well known, pure distilled water is unpalatable for drinking on account of its flatness. It is chiefly the carbonic acid and oxygen which render a water refreshing, as is shown by the fact that distilled water exposed for some time to the air loses most of its flatness and insipidity.

Lastly, if the *residue* left on the evaporation of a water turns *brown* or *black* on being heated, evidence is afforded of the presence of an excess of organic matter.

II. *Qualitative chemical tests.*—The reaction of the water may first be ascertained by means of litmus or turmeric paper. But, owing to the presence of free carbonic acid, drinking waters are mostly either neutral or slightly acid. After the removal of the carbonic acid, however, by heating the water, the true reaction will manifest itself. If, on the addition of a few drops of an ammoniacal solution of oxalate of ammonia, a white turbidity make its appearance, the presence of *lime* is proved. Although lime is rarely absent from any drinking water, the quantity present should be very small; and if therefore a strong white precipitate be thrown down by the above re-agent, the water must be pronounced to contain more lime in solution than is desirable, especially for washing purposes, for soap is decomposed by salts of lime and magnesia, insoluble stearate and oleate of lime and magnesia being the results, and thus large quantities of soap are actually lost, as has been more fully shown elsewhere.

Another small quantity of the water is to be boiled for half an hour in a glass flask. If it become turbid, the presence of carbonate of lime or magnesia is shown, which was held in solution by the carbonic acid removed by boiling. This is in so far in favour of the water as regards washing purposes, as by simply boiling it a part of the hardness may be removed, which purpose may also be effected by Clarke's softening process.

If, on the addition of a drop of a solution containing ferrocyanide and ferricyanide of potassium and pure hydrochloric acid, a blue coloration or precipitate ensues, the presence of *iron* is proved. Traces of iron are found in most waters, but larger quantities are objectionable.

Nessler's reagent is added to another portion of the sample contained in a glass cylinder or test-tube. A brownish-yellow coloration or precipitation indicates the presence in the water of *ammonia*; if the water become decidedly coloured, it is to be regarded as unfit for drinking, or at least in a very suspicious condition.

Another test frequently employed with a view to determine the quality of a water is the permanganate test; but this, as we shall now see, is very unreliable.

On the danger of reliance on the permanganate test.—This test, as is well known, acts by oxidation; that is, the permanganic acid, rich in oxygen, gives up its oxygen to many substances, such as the albuminoid organic matter present, in very variable quantities, in nearly all waters; to nitrous acid, also commonly contained in water, and even to protoxide of iron, not unfrequently present in drinking water in small amount and in the combined state. Nitric acid, likewise constantly found in impure waters in large amount, being an acid in the highest degree of oxidation of which it is susceptible, is unaffected by the permanganate, so that this test gives no indication of the presence of that acid; besides which, there is no possibility, by means of this test, of distinguishing between the hurtful and dangerous organic matter and the comparatively harmless nitrous acid or iron; in fact, the rule in using this test is to calculate all the oxygen abstracted from the permanganate into albuminoid matter.

Now let us see more precisely in what way this test fatally misleads in many cases.

A water analysed in the author's laboratory furnished the subjoined results per 70,000 grains:—

Total solids.	Nitrogen, as nitrates and nitrites.	Equal to nitric acid.	Organic nitrogen from albuminoid ammonia.	Equal to albuminoid organic matter.	Oxygen required by organic matter, nitrites, &c.
120·8	2·30	8·87	0·011	0·14	0·52

Now, it will be observed that the albuminoid organic matter—the really important element in potable waters—is, in this case, very small, and yet a very large quantity of the permanganate was destroyed by the nitrous acid, which was present in large quantity; therefore had only this test been relied upon, and had the oxygen been multiplied by 8, as the rule is, it would have given 4·16 grains of albuminoid organic matter in place of only 0·14 per gallon, and thus the water would be made out to be much worse, and in a more dangerous state, than was really the case.

The following instance is still more instructive. The water was sent, accompanied by the intimation that the party sending it believed it was a good water, as it had no action on the permanganate test; but that, since a medical gentleman in the town had declared it to be bad, it was deemed advisable to have a second opinion. On analysis, the results obtained were as follow:—

Total solids.	Nitrogen, as nitrates and nitrites.	Equal to nitric acid.	Organic nitrogen from albuminoid ammonia.	Equal to albuminoid organic matter.	Oxygen required by organic matter.
58·10	3·18	11·55	0·006	0·07	None.

The parties, therefore, who sent the water were quite correct in stating that it had no, or only a very trifling, action on the permanganate; but the inference that it was a good and safe water to use was fallacious and dangerous, for this water contained over 11½ grains of nitric acid; thus showing that it was subject to extensive pollution, though at the time of the examination nearly all the nitrogen was converted into nitric acid. But this process might not, from various circumstances, be always thus perfectly performed, and then the water might become deleterious and productive of disease. Here, then, we have a striking illustration of probable danger in the use of this test; and, since any mistake of this kind might involve health, and even life, it is manifestly wrong to place any reliance on this single test, uncontrolled by other results.

A third case, in which reliance on this test would have seriously misled, is the following. This water, on analysis, gave the subjoined results:—

Total solids.	Nitrogen, as nitrates and nitrites.	Equal to nitric acid.	Organic nitrogen from albuminoid ammonia.	Equal to albuminoid matter.	Oxygen required by organic matter.
121·10	5·27	20·32	0·024	0·30	0·061

In this sample the mineral constituents amounted to no less than 121 grains, and the nitric acid to over 20 grains per gallon; and yet only a very minute quantity of the permanganate solution was decolorised.

Lastly, a fourth water on analysis was found to furnish the following results:—

Total solids.	Nitrogen, as nitrates and nitrites.	Organic nitrogen from albuminoid ammonia.	Equal to albuminoid matter.	Protoxide of iron.	Oxygen required by organic matter and oxide of iron.
23·00	None.	0·01	0·12	0·39	0·095

In this case the quantity of albuminoid matter was small, yet a relatively very large quantity of the solution was decolorised, owing to the presence of the protosalt of iron. This water, really very pure, would, therefore, have been condemned by any person not experienced in such matters, using this test.

III. *Quantitative analysis.*—The quality of a water for either drinking, cooking, or washing purposes, depends chiefly upon two classes of constituents—organic matter of vegetable and animal origin, *non-nitrogenous*, *nitrogenous* and *mineral matter*. But even highly impure water contains only a few hundredths per cent. of solid matter in solution, so that the quantities the chemist has to deal with are usually extremely minute, especially as regards organic matter. Many methods have been proposed for the estimation of this latter, but even at the present time the problem cannot be considered to be perfectly solved, although much has been achieved in that direction and many valuable results have been obtained.

The organic nitrogenous matter changes under the influence of the oxygen of the air into nitric acid. We have, therefore, not only to direct our attention to the estimation of the organic matter present in the water, but also to that part, which has been oxidised, to the nitric acid, which gives therefore the indication of what has been called 'previous sewage contamination.' But nitric acid in water may be derived from another and totally different source—from the atmosphere. Wherever evaporation is going on, on a large or small scale, nitrite and nitrate of ammonia is formed, which salts are, therefore, always contained in the atmosphere, from which they are washed out by rain in its descent to the earth. Rain-water, therefore, contains nitric acid and ammonia, as has been before shown; these substances, however, not amounting, according to Frankland, to more than 0·024 nitrogen for the nitric acid and 0·008 for the ammonia, equal to 0·032 in 100,000 parts of water. This quantity of nitrogen, when found. in a drinking water, might therefore be derived from the atmosphere, but any larger amount must be due to contamination with animal matter.

Estimation of the organic matter.—Two processes are at present employed in this country for estimating the organic matter in water: the one, devised by Mr. Wanklyn, founded upon the fact that these substances give up their nitrogen in the form of ammonia by the action of a boiling alkaline solution of permanganate of potash; the other attempts a direct estimation of the nitrogen and carbon by heating the residue obtained by evaporation of the water with oxide of copper, and collecting and measuring the gases produced—chiefly nitrogen and carbonic acid—this latter method was devised by Professor Frankland. Besides these two methods several others exist, but as they are very imperfect and superseded by the two just pointed out, we think it unnecessary to describe them.

AMMONIA METHOD OF WATER ANALYSIS.

Requirements of the method. 1. *Nessler's Reagent.*—'Dissolve 35 grammes of iodide of potassium in a small quantity of distilled water, and add to it a strong aqueous solution of bichloride of mercury (corrosive sublimate), which will cause a red precipitate that disappears on shaking up the mixture. Add the solution of bichloride of mercury carefully, shaking up as that liquid is added, so as to dissolve the precipitate as fast as it is formed. After continuing the addition of bichloride of mercury for some time, a point will ultimately be reached at which the precipitate will cease to dissolve. When the precipitate begins to be insoluble in the liquid, stop the addition of bichloride of mercury. Filter. Add to the filtrate 120 grammes of caustic soda in strong aqueous solution (or about 160 grammes of potash).

'After adding the solution of alkali as just described, dilute the liquid so as to make its volume equal to one litre. Add to it 5 cc. of a saturated aqueous solution of bichloride of mercury. Allow to subside, and decant the clear liquid, which is the Nessler Reagent.'

We have given the preparation of this liquid in Wanklyn's own words, since it is the basis of the whole method. The reagent improves by age, so that it is advisable to make a large quantity, say one litre, at once. On exposure to the air it becomes turbid; it should be kept, therefore, in a well-stoppered bottle. With ammonia, or salts of ammonia, this liquid forms a brown precipitate, or, if only very little ammonia be present, a yellowish-brown coloration. The delicacy of this reaction is extreme, since it is not difficult to recognise $\frac{1}{400}$ of a milligramme of ammonia in 100 cc. of water, or equal to 2·5 parts in 10,000,000. The depth of colour varies with the quantity of ammonia present.

2. *A standard solution of ammonia.*—This is made by dissolving 0·3882 grammes of sulphate, or 0·315 grammes of pure chloride of ammonium, in one litre of perfectly pure distilled water; 1 cc. of this solution contains $\frac{1}{10}$ milligramme of NH_3. A second ten times weaker solution is prepared by diluting 100 cc. of this liquid with 900 cc. of pure distilled water, 1 cc. of this solution containing, therefore, $\frac{1}{100}$ milligramme of NH_3.

3. *Pure distilled water*, or water free from ammonia, is prepared by distilling water as rapidly as possible. The first quantity which passes over contains ammonia, the amount of which, however, decreases as the distillation progresses, and after a short time the water, tested with Nessler's Reagent in a test-tube or glass cylinder, will be found to be perfectly free from ammonia.

4. *A saturated solution of carbonate of soda* is prepared in the following way:—Anhydrous carbonate of soda, or bicarbonate of soda (which is easier to obtain in a dry state), is heated in a platinum basin to a red heat for about twenty minutes, and then dissolved while still hot in pure distilled water.

5. *An alkaline solution of permanganate of potash.*—Dissolve 200 grammes of caustic potash and 8 grammes of crystallized permanganate of potash in one litre of water, and boil the solution for at least one hour, to expel any ammonia.

It is not possible to bestow too much care upon the preparation of these liquids, and upon the cleaning of the vessels used. As we have said, the Nessler's Reagent is extremely delicate; each trace of ammonia gives a yellow coloration with it—in fact, it is the most sensitive of all reagents known. The utmost cleanliness is to be observed; bottles containing ammonia should not be opened before or during the operation, and the apparatus used should be protected from dust during distillation.

A retort capable of holding 1,500 cc. when in position for distillation, with well-fitting glass stopper, is connected with a Liebig's condenser by a piece of indiarubber tubing; about 500 cc. of pure distilled water are then introduced, and heated to boiling by a gas or spirit lamp. The steam which is produced cleans the apparatus much more effectually than could be done by any other means. The condenser is kept empty at first, till the steam has heated it thoroughly, and then filled with cold water. The condensed water is tested for ammonia, and the distillation continued till no further trace of that substance can be discovered. 15 cc. of the saturated solution of carbonate of soda are then introduced and boiled with the water. The distillate is to be tested again. It should be free from ammonia, thus proving that the solution of carbonate of soda is pure. If not, this solution is to be boiled for an hour. If then found pure, 50 cc. of the solution of permanganate of potash are measured into the retort, and tested for ammonia in the same way. All reagents must be free from even a trace of that substance.

If all be in right condition, the estimation of ammonia in the water to be analysed may be proceeded with.

Estimation of free ammonia.—500 cc. of the water are measured into the carefully-cleaned retort; 15 cc. of the carbonate of soda solution are then added, and the mixture, which commonly turns turbid, caused by the precipitation of the salts of lime and magnesia contained in the water, distilled till the last 50 cc. of the distillate contain no more ammonia—*i.e.*, till Nessler's Reagent fails to produce the slightest yellowish tinge with the distillate. It is commonly sufficient to distil from 150 to 200 cc.—in most cases less will be enough; and it is only in very bad water that the distillate contains, even after that, more ammonia.

The distillate is to be transferred to cylinders holding about 110 cc., graduated at 100 cc.; 100 cc. of the distillate, which now contains all free ammonia, are used, and $1\frac{1}{2}$ or 2 cc. of Nessler's Reagent added to it. The colour is to be observed, and from a burette so much of the standard solution of ammonia which contains in 1 cc. $\frac{1}{100}$ milligramme, is to be filled into another similar cylinder as may be thought necessary to produce the same depth of coloration with Nessler's Reagent if diluted with distilled water to 100 cc. Both liquids are allowed to stand for at least ten minutes, and then the colour is observed. If the coloration of both liquids be equal, both contain the same amount of ammonia. The quantity of the volatile alkali contained in the one cylinder is known, since a measured quantity of standard ammonia solution has been introduced. The amount of ammonia contained in 100 cc. of the distillate must be equal to this added amount. If, on the other hand, the coloration of the two liquids be different, a third cylinder is to be filled with the pure distilled water, a smaller or larger amount of standard solution than at the first experiment being added, and 1½ cc. of Nessler test, and after another ten minutes the colour is again observed. With a little practice it is easy to judge with considerable accuracy how much of the standard solution is to be used. An example will illustrate this description.

500 cc. of water have been subjected to distillation. 200 cc. of distillate contained all the free ammonia. 100 cc. of this distillate were filled into the cylinder, and 1½ cc. Nessler test added. 3·5 cc. of standard ammonia solution dropped into a second cylinder, diluted with 100 cc. of pure water, gave with Nessler test too light a coloration. It is not advisable to add more of the standard solution to the liquid, since it always turns turbid if the Nessler test be added before the ammonia. Into a third cylinder 3·8 cc. were filled and tested as before; colorations equal. 100 cc. of the distillate contain, therefore, so much of free ammonia as are contained in 3·8 cc. of standard solution—namely, 0·000038 grammes. The total distillate (200 cc.) contains, therefore, 0·000076 NH_3, or, what is the same, 500 cc. of the original water contained 0·000076 of ammonia. 100,000 parts of water contain, therefore, 0·0152 parts of free ammonia.

Estimation of albuminoid matter.—The residue in the retort, from which all free ammonia has been expelled, contains unaltered the albuminous organic matter. 50 cc. of the alkaline solution of permanganate are added to it, and the mixture distilled as before. The nitrogen of the organic matter is liberated during the distillation as ammonia, passes through the condenser, and is collected and estimated exactly as the 'free ammonia.' Much has been said for and against this process. Wanklyn himself admits that the *whole* of the nitrogen is not obtained by this method. We shall consider below the merits and the defects of the process.

In the case of bad waters the inner surface of the retort is covered with a thin film of dioxide of manganese, which causes the liquid to boil very irregularly, to bump with great force, and rise even so high as to colour the distillate red, which is then to be poured back into the retort. A few pieces of tobacco-pipe, heated previously to destroy any organic matter and remove any ammonia which might be present, put into the retort, prevent by their constant movement the formation of this film, and consequently the rising of the liquid.

Estimation of nitrogen as nitrates and nitrites. — A great many methods for the estimation of nitrates have been proposed. Those generally employed in this country are, however, only two—Schulze's, as modified by Chapman, and Crum's, as modified by Frankland. We shall consider this latter one under 'Frankland's Method of Water Analysis.' Chapman describes his process as follows:—'100 cc. of the water are introduced into a non-tubulated retort, and 50 to 70 cc. of a solution of caustic soda added. The caustic soda must be free from nitrates, and the strength of the solution should be such that 1 litre contains 100 grammes of caustic soda. The contents of the retort are to be distilled until they do not exceed 100 cc., and until no more ammonia comes over; that is, until Nessler's test is incapable of detecting ammonia in the distillate. The retort is now cooled, and a piece of aluminium introduced into it (foil will answer very well with dilute solutions, but we much prefer thin sheet aluminium in all cases). The neck of the retort is now inclined a little upwards, and its mouth closed with a cork, through which passes the narrow end of a small tube filled with broken-up tobacco-pipe, wet either with water, or better, with very dilute hydrochloric acid free from ammonia. This tube need not be more than an inch and a half long, nor longer than a goose quill. It is connected with a second tube containing pumice stone moistened with strong sulphuric acid. This last tube serves to prevent any ammonia from the air entering the apparatus, which is allowed to stand in this way for a few hours or over-night. The contents of the pipe-clay tube are now washed into the retort, with a little distilled water free from ammonia (about 70 to 80 cc.).

We have now a strongly alkaline liquid, which contains all nitrogen derived from the nitrates and nitrites in the form of ammonia. It is distilled, and in the distillate the ammonia estimated as 'free ammonia.' It is advisable to fill into the receiver about 150 to 200 cc. of pure distilled water, and to let the tube of the Liebig condenser dip under the surface of the water, so as to avoid any loss of ammonia.

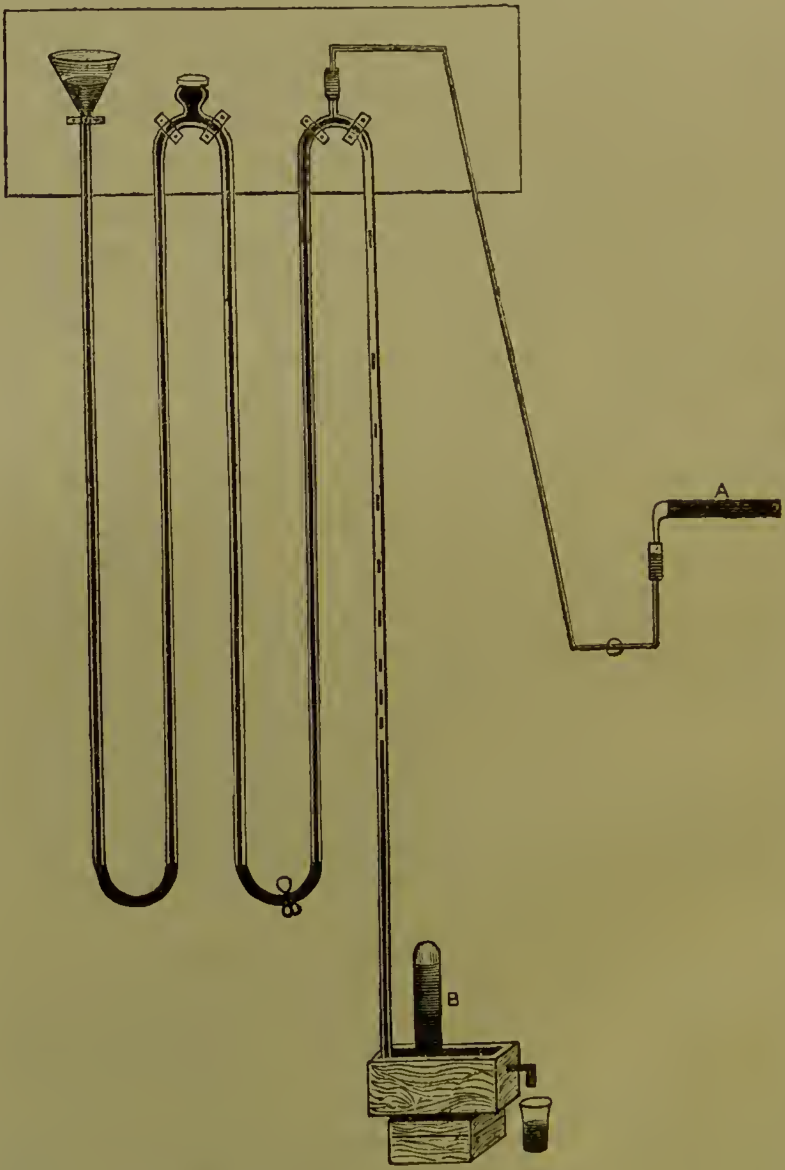
Seventeen parts of ammonia are equal to 63 parts of nitric acid (HNO_3).

Frankland's Method of Water Analysis.

As already mentioned, this method is based upon the principle, that when the residue on evaporation of the water is burned with oxide of copper, nitrogen and carbonic acid are eliminated from the organic matter, and are then collected and measured.

One litre of the water is to be taken and boiled for two minutes in a glass flask after 30 cc. of a concentrated solution of pure sulphurous acid have been added. The addition of sulphurous acid serves a twofold purpose—for decomposing the carbonates naturally contained in nearly every water, and for eliminating the nitrogen of the nitric acid of the water as nitric oxide. If this precaution were not taken, the

Fig. 15.



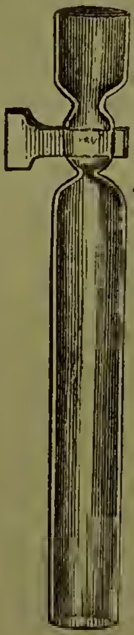
Sprengel's Mercury Air-Pump.

A, combustion tube; B, tube for collecting the gases produced by combustion.

carbonic acid of the carbonates would be found with the organic carbon and the nitrogen of the nitric acid with the nitrogen of the organic matter.

The water is then evaporated with the addition of about 0·2 gramme of sulphate of soda, and a few drops of ferric chloride; the former for neutralising any sulphuric acid formed during evaporation by oxidation of the sulphurous acid, the latter for insuring the completest possible decomposition of the nitric acid. Half-spheric glass basins, capable of holding about 100 cc., are employed for the evaporation of the water on a water or steam bath. Glass shades, such as are used for covering ornaments, are placed over the basins, so as to prevent any ammonia or atmospheric dust from contaminating the sample. The evaporation is rather slow. The perfectly dry residue is now mixed with oxide of copper by means of a flexible steel spatula, and filled into a strong combustion tube, fused round on one end. The oxide of copper must be prepared by heating metallic copper in the air, and not by oxidising it by means of nitric acid, and then heating it to redness, as the oxide of copper used for organic analysis is usually prepared, since in the latter case it is impossible even by repeated heating to get rid of all nitric acid. The combustion tube is nearly filled with the oxide, and a spiral of metallic copper is inserted in the end of the tube, so as to touch the oxide. The glass tube is then drawn out over the blowpipe, and the air contained in it is perfectly exhausted by means of a Sprengel mercury air-pump, as shown in fig. 15.

Fig. 16.



The tube containing the water residue is then heated as in an ordinary organic combustion in a combustion furnace, and as soon as the whole tube is red hot, the air-pump is set in action, and the produced gases are received in a test-tube, from whence they are removed into the apparatus constructed by Professor Frankland and delineated in fig. 17.

The following different gases are the product of the combustion:—

Sulphurous acid, produced from the sulphite of soda.

Carbonic acid, from the carbon of the organic matter.

Nitric oxide } from the nitrogenous matter.
Nitrogen }

Carbonic oxide.

Oxygen, in some cases, if no nitric oxide be present.

The sulphurous acid is first removed by means of a solution of bichromate of potash, whereby it is oxidised to sulphuric acid. The residual gases are now accurately measured (*a*). The carbonic acid is then absorbed by a strong solution of caustic potash and the gases are measured again (b). Some pyrogallic acid is now introduced into the apparatus for the absorption of oxygen, if any be present. We call the residual mixture (c). If no oxygen be found—*i.e.*, if $b = c$—some bubbles of pure oxygen are added to the mixture. They convert the nitric oxide present into nitric tetroxide, which is absorbed with the excess of oxygen, by the alkaline solution of the pyrogallic acid.

From the residue (d) consisting of nitrogen and perhaps carbonic oxide, this latter gas is absorbed by means of a solution of cuprous chloride and the nitrogen measured (e).

$a - b$ gives the volume of carbonic acid.

$c - d$ represents the volume of nitric oxide.

$d - e$ gives the quantity of carbonic oxide, and

e the quantity of nitrogen.

The carbon contained in the carbonic acid is added to the carbon of the carbonic oxide, giving the total amount of carbon in one litre of the water; while the nitrogen of the nitric oxide, added to the nitrogen, found as such, gives the total amount of nitrogen in the aame quantity.

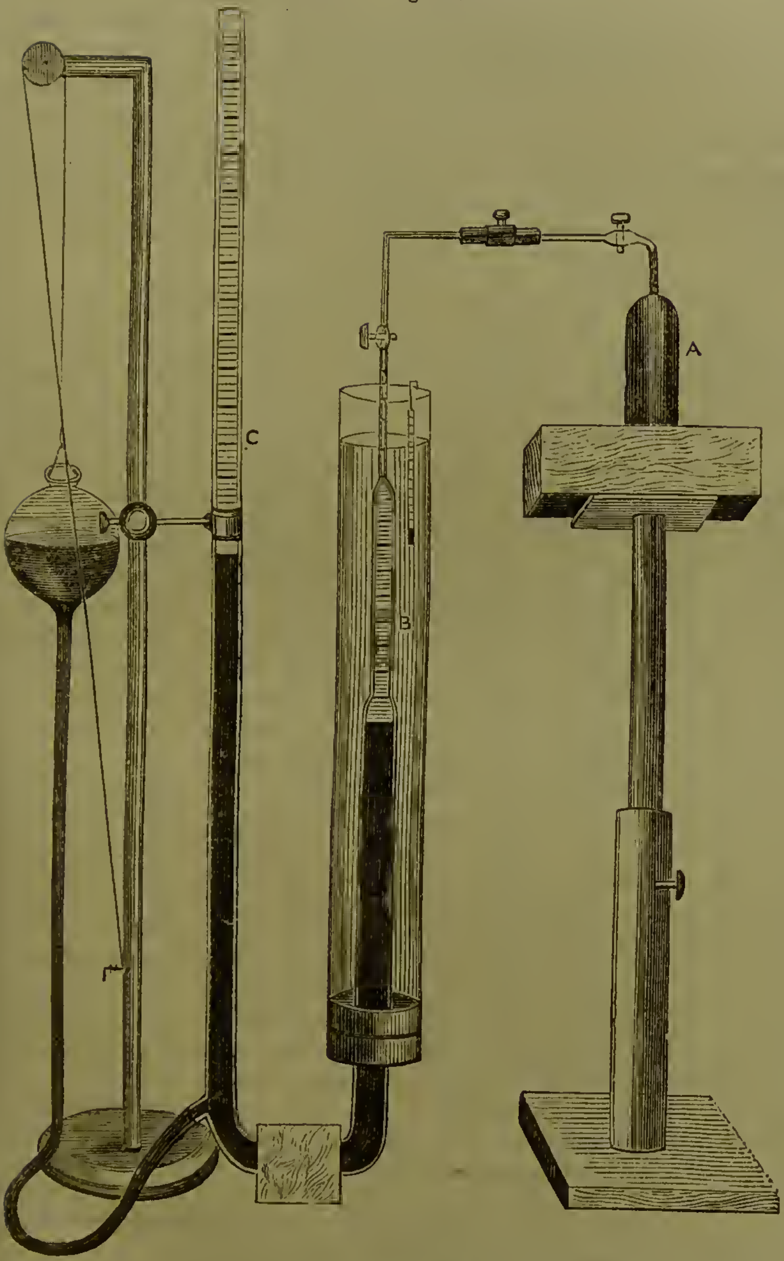
Several blank experiments with pure distilled water should be made; a small quantity of carbon and nitrogen will always be found, which, if once determined, is to be subtracted in all cases from the results found by the analysis of a water.

Frankland's Method for estimating the nitric and nitrous acid.—A measured quantity of the water is evaporated to a small bulk, and the chlorine is removed from it by means of sulphate of silver. The filtrate is evaporated to a few drops in a small beaker, and then introduced with strong sulphuric acid in a tube closed at one end and filled with mercury (fig. 16). The nitric acid acts upon the mercury, and soon an evolution of nitric oxide will begin, which is much aided by violently shaking the tube. The gas evolved is transferred to the same apparatus in which the gases obtained from the combustion of the water residue were measured, and calculated for nitrogen.

Comparison between Wanklyn's and Frankland's Methods.—Each of the two methods for determining the organic matters has its weak as well as its strong points. While Wanklyn's method can be completed in an hour or two, Frankland's requires at least two days for evaporation, combustion, and measurement of the gases produced. In a laboratory where many water analyses are to be made, it is a great inconvenience to have an evaporation going on for so long a time, during which it is impossible, even with the most scrupulous care, to avoid contamination with organic dust or with ammonia. And, if after so much trouble a combustion tube breaks, as may easily happen, the tube being exhausted, the day's work is lost.

The time required for the evaporation of the water can now however be very much shortened by the adoption of a contrivance proposed by

Fig. 17.



Frankland's Apparatus for Gas Analysis.

A, vessel to receive the mixed gases to be analysed; B, graduated tube in which the gases are measured; C, graduated tube, to measure the pressure to which the gases are subjected.

G. Bischof. The water is contained in a glass balloon, in the neck of which is accurately ground a bent tube; the balloon is inverted over the dish in which the water is to be evaporated, and thus the water removed by evaporation is continually replaced until the whole of the litre is evaporated. Thus 30 hours are sufficient for the evaporation.

Wanklyn's method may be finished in a very short time, and may easily be repeated in case of an accident. It requires, moreover, nothing but a retort and a condenser; while, on the other hand, Frankland's apparatus, with its 30 to 40 lbs. of mercury, involves considerable cost. So much as to cost and time.

The accuracy of the methods is, of course, a point of infinitely higher importance. Wanklyn admits that boiling with an alkaline permanganate does not yield the whole of the organic nitrogen: it does not even yield a constant fraction of it. He experimented upon a variety of substances, and found very considerable variations of the percentages of nitrogen obtained from various nitrogenous compounds. Thus, albumen gave only 10 per cent. of nitrogen, whilst actually it contains nearly 16, and casein, with the same amount of nitrogen, even gave as little as 7·6 per cent. Wanklyn proposes to calculate 1 part of albuminoid ammonia as 10 parts of albuminoid matter, but even thus the approximation to the truth can only be very slight. Accurate results cannot, therefore, be expected by his method. They are very good, however, for comparison. A bad water will appear bad, and a good one will appear good, by his method, although the absolute quantities of organic matter cannot be thus determined. Moreover, no idea is given of the amount of carbon present in the water, also a point of the highest importance.

Frankland's method has a real scientific basis; it is good and sound in principle, which Wanklyn's is not. It appears a very easy proceeding to evaporate the water and estimate by combustion the nitrogen and carbon, but there are many practical difficulties. As already mentioned, during the prolonged evaporation some amount of contamination with extraneous organic matter cannot be prevented, especially as we have to deal only with a few milligrammes of substance. It has further been urged, and with much reason, that the free sulphuric acid produced during evaporation acts upon the organic matter, partly decomposing it. Frankland himself admits contamination of the water during evaporation when he directs that several blank experiments should be made by the analyst and the average of the results obtained subtracted in all cases from the results of every subsequent analysis. Frequently this correction surpasses in quantity the amount of organic matter in pure waters. In the latter case only a few hundreths of a cubic centimetre of nitrogen are obtained, which cannot possibly be measured with great accuracy.

A great number of analyses made by either method have brought the author to the following conclusions:—

In all cases, where only the *quality* of a drinking or other water is to be determined, Wanklyn's method gives satisfactory results; in those cases, however, where the *quantity* of organic matter, and especially the *quantity of carbon*, is required, Frankland's method is to be preferred. This latter should, and no doubt will, supersede the permanganate process.

Both methods for the estimation of nitric acid give very accurate results, if the quantity of nitrates present be but moderate.

All the apparatus required for water analysis by Frankland's method may be obtained of Messrs. Cetti, Holborn.

ESTIMATION OF THE MINERAL CONSTITUENTS OF WATER.

Determination of the total solid residue.—300 to 500 cc. of the water are to be evaporated in a weighed platinum basin on the water-bath, and the residue is to be dried in the air-bath at about 110° C. The result is to be calculated for 100,000 of water.

The weighed residue is then heated over the open flame, and it is carefully noted whether it turns brown or black on igniting, indicating the presence of carbonaceous matter. The loss by ignition may be determined, but it gives no reliable data as to the quantity of organic matter present, since chloride of calcium retains, when dried at 110° C., a not inconsiderable proportion of absorbed water, and, further, since chloride of magnesium is decomposed by heating, suffering a decrease of weight which would of course be calculated as organic matter.

Estimation of chlorine.—Chlorine may be estimated either gravimetrically or volumetrically. For the first method of estimation 500 to 1,000 cc. are evaporated to a small bulk, and the chlorine is then precipitated by means of nitrate of silver. The chloride of silver is filtered, washed, dried, and weighed. 100 parts of AgCl contain 24,724 parts of chlorine.

For the volumetric estimation, a solution of nitrate of silver of known strength is required. It is prepared by dissolving in 1 litre of distilled water 0·479 gramme of pure crystallised nitrate of silver. 1 cc. of this solution precipitates 0·0001 gramme of chlorine.

100 cc. of the water are measured in a beaker, 2 or 3 drops of a saturated solution of neutral chromate of potassium are added, and then from a burette the standard silver solution is dropped into the yellow-coloured water. Each drop produces a brown coloration, which at first rapidly disappears. Soon, however, this coloration becomes permanent and the number of cc. of silver solution used is noted, and from it the quantity of chlorine is calculated.

The principle upon which this method is based is the following:—Silver has a greater affinity for chlorine than for chromic acid. If, therefore, a solution of silver be added to a liquid containing both chlorine and chromic acid, the former will be first perfectly precipitated before chromate of silver, as a reddish-brown precipitate, begins to form. As soon therefore as the brown coloration is permanent, all chlorine is precipitated. It is absolutely necessary for the success of the method that both the nitrate of silver solution and the liquid in which the chlorine is to be estimated are exactly neutral.

Estimation of nitrous acid.—It would be extremely desirable that a method for the exact determination of the nitrous acid should be known, but unfortunately such is not the case. The processes proposed can only be regarded as giving approximations to the truth. They are all founded upon the reaction, with only slight modifications proposed by different chemists, which permanganate of potash undergoes by coming into contact with nitrites—namely, instantaneous decolorisation.

Thus, Dr. Paul works in the following way:—1 litre of the water is mixed with a few drops of chloride of aluminium, and then with an equivalent quantity of carbonate of soda. The quantity of standard permanganate solution decolorised after this proceeding is then ascertained, and from it the amount of the nitrous acid is calculated. But it is erroneous to suppose that *all* organic matter is carried down with the hydrate of alumina formed by the addition of carbonate of soda to chloride of aluminium, and the quantity which is left in solution and acted upon by the permanganate doubtless exceeds, in many cases, by far the quantity of nitrous acid present.

Dr. de Chaumont's plan is to acidulate a measured quantity of the water, say half a litre, with sulphuric acid, and to boil it. The nitrous acid is thus liberated and thrown off. The difference between the quantity of permanganate used before and after boiling would indicate the amount of nitrous acid. And, indeed, this plan seems to be corroborated by an observation recently made by Prof. Fresenius, that nitrous acid is volatile without decomposition. It would therefore, no doubt, be more advisable to distil a measured quantity of the water, and to estimate in the distillate the quantity of nitrous acid by means of permanganate.

Estimation of dissolved gases in water.—We here include only oxygen, nitrogen, and carbonic acid, these being the chief gases present in potable waters in quantities sufficiently large to allow of direct measuring. They are obtained from the water in which they are dissolved in two ways; namely, either by boiling, or by exhausting by means of the air-pump. In whatever way obtained they are measured by any of the methods of gas analysis, and analysed in the same manner as the gases produced by the combustion of the water residue with oxide of copper, as practised in Dr. Frankland's method of water analysis, to which the reader is referred.

Estimation of sulphuretted hydrogen.—The quantity of this gas contained even in the very worst of waters is so small that it cannot be estimated by any gravimetrical method; that is to say, by the precipitation of it by means of a solution of any of the heavy metals.

The volumetrical method employed, is in its simplest form, executed as follows:—A very dilute solution of iodine in an aqueous solution of iodide of potassium is first prepared by dissolving a weighed quantity of iodine. This element acts upon sulphuretted hydrogen, as indicated by the following formula:—$I_2 + H_2S = 2HI + S$. 127 parts of iodine correspond, therefore, to 17 parts of sulphuretted hydrogen.

A litre of the water to be examined is measured into a large beaker, a few drops of a solution of starch are added, and then from a graduated burette the standard iodine solution is dropped in. After the destruction of the sulphuretted hydrogen, the iodine combines with the starch, striking a blue coloration, which gives therefore the indication that a sufficient quantity of iodine has been added. From the number of cc. used, the proportion of sulphuretted hydrogen contained in the water is easily calculated by means of the above-given formula and figures.

Estimation of sulphuric acid.—500 to 1,000 cc. of the water are evaporated to a small bulk, acidulated with pure hydrochloric acid, and the sulphates are then precipitated by the addition of a solution of chloride of barium. The precipitate is filtered, washed with boiling water, incinerated and weighed. 100 parts of it contain 34·335 parts of sulphuric anhydride, SO_3. It may here be remarked, that it is convenient to calculate all results for the anhydrous bodies, and not for the hydrates, since by the combination of a hydrated acid and base, water is eliminated, which would involve therefore a further calculation.

Estimation of silica, iron and alumina, lime and magnesia.—1,000 cc. of the water are evaporated in a platinum basin to dryness on the water-bath, after the addition of some hydrochloric acid. The residue is moistened with dilute acid, dissolved in hot water, and the silica remaining is collected on a filter, washed, incinerated and weighed.

To the filtrate chloride of ammonium is now added, and then the iron and alumina are precipitated by means of caustic ammonia; the precipitate, which is usually very small, is collected on a filter, and since it might contain lime, it is again dissolved in acid and precipitated as before. The filtrates are joined, and the precipitate is weighed. A separation of the oxide of iron and of the alumina is not necessary in the case of drinking waters.

To the alkaline filtrate an excess of oxalate of ammonium is now added; this precipitates the lime as white insoluble oxalate of lime, which is separated by filtration after twelve hours' standing. It is washed and very gently heated in a weighed platinum crucible, which must not be allowed to get red hot. The oxalate is thereby converted into the carbonate of lime, which may be weighed. But the carbonate after conversion in the crucible into the sulphate, by treating it with strong sulphuric acid, should be ignited and weighed. 100 parts of carbonate of lime contain 56·00 parts of lime, CaO, while 100 parts of the sulphate correspond to 41·176 parts of lime. Both estimations should give nearly identical quantities.

The liquid, from which the oxalate of lime has been removed by filtration, is evaporated to dryness in a platinum basin, and the salts of ammonia are driven off by heat. The residue, containing the magnesia as carbonate, is dissolved in pure hydrochloric acid, ammonia added to the filtered liquid, and the magnesia precipitated as phosphate of magnesia and ammonia by means of a solution containing phosphate of soda and chloride of ammonium. After twenty-four hours' standing, this precipitate is filtered, washed with dilute ammonia (1 : 4), incinerated and weighed. The precipitate is converted by incineration into pyro-phosphate of magnesia, $Mg_2P_2O_7$. 100 parts of this substance are equal to 36·036 parts of magnesia.

Estimation of soda.—1,250 cc. (or any other quantity, but this is the most convenient for calculation) are evaporated to about 150 or 200 cc., and then milk of lime is added till the liquid is just alkaline. It is put into a flask graduated at 250 cc., and filled up to the mark with distilled water. The precipitate is allowed to settle, and 200 cc. of the clear liquid are taken out by means of a pipette. These 200 cc. represent 1,000 cc. of the original water. They are put into another 250 cc. flask, and ammonia, carbonate of ammonia, and some oxalate of ammonia are added, and water to make up 250 cc., filtered, and 200 cc. of the filtrate, equal to 800 cc. of water, are evaporated, with the addition of some chloride of ammonium, incinerated, and the chloride of sodium thus obtained is weighed.

Potassium occurs only in small quantity in drinking waters. It may be separated, however, should any be present, from the chloride of sodium by means of chloride of platinum (see Fresenius).

The soda may be estimated indirectly as follows :—

The residue obtained by the evaporation of 1,000 cc. of water is weighed as described for total solids. After weighing, a little water, and some dilute sulphuric acid, are added, care being taken to avoid loss by spirting. Evaporate and drive the sulphuric acid off at a red heat. The residue is weighed. It consists of silica, oxide of iron and alumina, and the sulphates of lime, magnesia, and soda. Subtract from it the quantities of silica, oxide of iron and alumina actually found, calculate the quantities of lime and magnesia obtained into sulphates, and subtract them; the rest is sulphate of soda, which is to be calculated for soda Na_2O. 100 parts contain 43·658 of Na_2O. The result obtained by this indirect method should closely correspond with that of the direct estimation.

Estimation of combined carbonic acid.—The carbonic acid may be estimated directly or by calculation. Also in this case one result may be used to check the other. For direct estimation 1,000 cc. of water are to be evaporated in a glass flask to a very small bulk, about 50 cc. The liquid is coloured by tincture of litmus, and dilute sulphuric acid of known strength is gradually added to the boiling liquid, till the reaction is just acid. The volume of acid used gives the quantity of carbonic acid, 20 parts of SO_3 being equal to 11 of CO^2.

The calculation of the quantity of carbonic acid without direct estimation is as follows:—

Calculate how much sulphuric acid (SO_3) corresponds to the quantities of lime, magnesia, and soda found, and subtract from this the quantity of SO_3 directly found, also amounts equivalent to the nitric acid and the chlorine found. The remainder of sulphuric anhydride is equivalent to the combined carbonic acid.

The quantity of *total solids* directly found should be nearly equal to the quantity of the different constituents separately estimated, taking into consideration that for each molecule of chlorine an atom of oxygen is to be subtracted. The correspondence cannot be expected to be absolute, for several reasons. The silica acts during evaporation and drying upon the carbonates, driving out some carbonic acid; carbonate of magnesium loses some carbonic acid; and, lastly, chloride of magnesium cannot be dried without decomposition, and the loss of part of its chlorine as hydrochloric acid and the formation of magnesia.

Estimation of phosphoric acid.—In most waters traces of phosphoric acid may be found if only properly looked for. Its amount is mostly, however, so small that large quantities of water must be evaporated to render a quantitative estimation possible. In highly contaminated and impure waters phosphoric acid is sometimes present in comparatively large amount. Its estimation may be thus effected. 1 litre of water is evaporated to dryness in a porcelain dish, with the addition of a few drops of nitric acid. The residue is moistened with nitric acid and dissolved in boiling water. The liquid, the amount of which should not exceed 20 cc., is filtered through a small filter, and precipitated with an excess of a solution of molybdate of ammonia in nitric acid. The yellow precipitate of phosphomolybdate of ammonia is filtered after twenty-four hours' standing, washed with some molybdate of ammonia, dissolved in weak caustic ammonia, and in the solution the phosphoric acid is precipitated with magnesium chloride. The white and crystalline precipitate of phosphate of ammonia and magnesia is filtered, washed, incinerated, and weighed. 100 parts of the incinerated precipitate contain 63·96 parts of phosphoric acid (P_2O_5).

The calculation of the results.—It is impossible to tell with certainty how all the substances found and estimated as described are combined in the water. Thus we might mix nitrate of soda and chloride of potassium together, and we are no longer able to say which salts the solution contains. Very probably double decomposition takes place, and in solution are now, instead of two, four salts—namely, the two salts mixed and nitrate of potash and chloride of sodium. In other cases we may be certain in which state of combination the different bodies are; we know, for instance, that if we find a water to contain carbonate of soda, chloride of calcium cannot be present, these two salts decomposing each other, forming carbonate of calcium and chloride of sodium. Further, we cannot determine by evaporation and the forms of the crystals which salts were originally present, since double decomposition prevents any accurate conclusions; thus, we dissolve together nitrate of soda and chloride of magnesium, and if we then evaporate, we get in the very concentrated solution crystals of chloride of sodium, notwithstanding that this substance was not present originally.

Some information as to the manner in which the mineral substances dissolved in water are combined may be obtained, by separating the *soluble* from the *insoluble* portion of the residue, by means of a very small quantity of distilled water; also by a partial evaporation of the water, whereby the earthy carbonates are separated from the other constituents.

Certain rules may, however, be observed, which cannot lead far wrong. If several salts are brought together in solution they always combine so as to form the most insoluble combinations. We are sure, for instance, that if we find in a water barium, chlorine and sulphuric acid, if such a case were possible, the barium must be combined with the sulphuric acid.

Fresenius, the highest authority on water analysis, gives the following directions for the calculation of the results:—'The chlorine is combined with the sodium; if there is an excess this is combined with calcium. If, on the other hand, there remains an excess of soda, this is combined with sulphuric acid. The sulphuric acid, or the remainder of the sulphuric acid, as the case may be, is combined with lime. The nitric acid is, as a rule, to be combined with lime. The silica is put down in the free state, the remainder of the lime and the magnesia as carbonates.

'It must always be borne in mind, that the results of the quantitative analysis may render another arrangement of the acids and bases necessary. For instance, if the evaporated water reacts strongly alkaline, carbonate of soda is present, generally in company with sulphate of soda and chloride of sodium, occasionally also with nitrate of soda. The lime and magnesia are then to be entirely combined with carbonic acid.'

Estimation of hardness.—We have already described the exact chemical methods for the estimation of lime and magnesia. For practical purposes it is, however, frequently sufficient to determine the total quantity of lime and magnesia, if not with exactness, at all events with very close approximation to the truth. The method employed for this purpose is that proposed by Prof. Clarke, and is founded upon the following facts. Common soap consists chiefly of oleate and stearate of soda, which salts are both soluble in water. If a solution of soap is mixed with one of a salt of lime or magnesia, stearate and oleate of these bases are formed, which, being insoluble, form a white precipitate. It is evident that an amount of soap will thus be precipitated, which stands in proportion to the quantity of lime and magnesia present, or, in other words, which is equivalent to it. If, therefore, a solution of soap of known strength be prepared and added to a measured quantity of the water to be tested, a lather characteristic of soap cannot be formed on shaking, until the whole of the lime and magnesia are precipitated, and, moreover, a small excess of the soap solution is added. The volume of the soap solution used will thus give the proportion of the alkaline earths.

It will further be seen, that 56 parts of lime will destroy or precipitate just as much soap as 40 parts of magnesia, these being the equivalents of the two bases. The soap-test does not allow of a discrimination of lime and magnesia; the total amount must either be expressed and calculated for lime or for magnesia. Lime being usually the prevalent constituent, the figures are based upon the amount of this substance. In England it is customary to calculate the results not as lime but as carbonate of lime, and to call 1 grain of carbonate of lime in 1 gallon, or 70,000 grains of water, 1 *degree of hardness*, whilst other countries, as France and Germany, calculate as caustic lime, and call 1 part of caustic lime in 100,000 parts of water 1 degree of hardness.

The details of the process and the preparation and standardising of the soap solution are as follow. It is absolutely necessary to adhere strictly to these details if satisfactory results, and figures agreeing among themselves, and with those of other observers, are expected.

A solution of lime of known strength is first prepared by heating pure chloride of calcium just to redness in a weighed platinum crucible, allowing to cool over sulphuric acid, and reweighing when cold. About half a gramme is thus accurately weighed and dissolved in such a quantity of water that 1,000 cc. or 1 litre contains 1·110 gramme of chloride of calcium, equal to 1 gramme of carbonate of lime in 1 litre of water; 1 cc. therefore corresponds to 0·001 gramme of carbonate of lime.

40 grammes of lead plaister are finely powdered in a mortar, and then intimately mixed with 20 grammes of carbonate of potash, with the addition of a few drops of water. The mass is then repeatedly treated with cold methylated spirit, which dissolves easily the soap or oleate of potash thus formed, while insoluble carbonate of lead, and the excess of carbonate of potash, are not taken up by the alcohol. The amount of alcohol should be about 30 times the weight of the lead plaster taken. This soap solution is diluted with its equal volume of water. It now requires standardising. 70 cc. of distilled water are measured into a stoppered bottle, capable of holding about 250 cc., and 10 cc. of the unstandardised soap solution are added to it. From a burette, divided into tenths of cubic centimetres, the standard chloride of calcium solution is then slowly added. The mixture is from time to time well shaken. As long as the liquid froths or lathers on shaking, undecomposed soap is present, and more of the chloride of calcium solution is to be added. At the point when lather no longer appears, the volume of the calcium solution is then accurately read off, and we find thus how much of this solution is necessary to decompose 10 cc. of the soap solution. This latter will be found to be much

stronger than the calcium solution. It is then calculated how much water must be added to it in order to render it of such a strength that 17 cc. of the soap solution require 16 cc. of the calcium solution for perfect decomposition.

Properly 1 volume of the one solution ought to neutralize 1 volume of the other, but it is evident that, to produce lather, a slight excess of soap must be added, hence the above figures. After dilution of the soap-test, the standard should be verified again by experiment.

The employment of the standard soap solution, obtained as described, is as follows :—

100 cc. of the water to be tested are measured into a stoppered bottle, and with frequent shaking the soap-test is added from a burette. As soon as a permanent lather is formed, which will remain for five minutes, the addition is stopped. The number of cc. of the soap used gives the quantity of carbonate of lime in 100,000 parts of water. If, after the addition of 24 cc. of soap, lather does not appear, 100 cc. of distilled water are added, and afterwards from the total quantity of soap solution used 1 cc. is subtracted.

If it is desired to obtain *degrees* of hardness, *i.e.*, calculate the result for one gallon, 70,000 grains of water, the figure is simply to be multiplied by 0·7.

Thus we obtain what is called *total hardness*, which is the measure of the total soap-destroying power of the water. This, as we have explained above, is mainly due to all salts of lime and magnesia present. A part of these salts is permanently soluble in water, as the chlorides, sulphates, and nitrates, whilst the carbonates of lime and magnesia are as such insoluble in pure water. They, however, dissolve in considerable quantity in water containing free carbonic acid, soluble bicarbonates being formed. By boiling the dissolved carbonic acid is driven away, and consequently the carbonates of lime and magnesia, their solvent being removed, separate in the form of microscopical crystals. The hardness, of course, is reduced in proportion to the quantities of carbonates of these two bases present.

The *permanent* hardness is estimated by boiling 100 cc. of the water for three-quarters of an hour in a platinum basin, adding at intervals distilled water to make up for the loss by evaporation; or the water may be evaporated to about one-third of the original bulk, but then it must be diluted and boiled again with distilled water, to take up any sulphate of lime which might have separated in a crystalline form; but this latter case will rarely, if ever, happen, since the solubility of gypsum is rather considerable. After the lapse of that time the water is allowed to cool, filled up to its original bulk, transferred into the stoppered bottle, and its hardness estimated as described. The loss of hardness by boiling is called *temporary* hardness.

Detection and determination of lead and copper.—We have shewn in a previous chapter that lead is, under certain circumstances, dissolved by water in quantities sufficient to be attended by injurious effects. These quantities are, however, mostly too minute to be detected in the water in its unconcentrated condition, and to effect its determination it is always necessary to evaporate it to a smaller bulk. This operation is performed in porcelain dishes, with the addition of a drop or two of hydrochloric acid, so as to slightly acidulate the water. If by the addition to a portion of this concentrated liquid of a few drops of sulphuretted hydrogen dissolved in water, a dark coloration is produced, one of the series of the heavy metals is sure to be present. This may be either *copper* or *lead*, but in most cases the latter metal. To ascertain which of them is present in a special case, much larger quantities of the water must be evaporated and tested. From three to four litres of water are evaporated to a small bulk, with the addition of a few drops of nitric acid. Sulphuretted hydrogen is passed through the liquid for about three or four hours, and the black precipitate which forms, if either lead or copper is present, is collected on a filter and washed with water containing some sulphuretted hydrogen. It is then boiled with pure nitric acid and evaporated on the water-bath, with the addition of a drop of sulphuric acid, and moistened again with distilled water. The residue, if any, consisting of sulphate of lead, is collected on a filter, and the filtrate tested after neutralisation with ammonia and acidulation with acetic acid, with a solution of ferrocyanide of potassium, which will give rise to a red precipitate if any *copper* be present.

The quantitative estimation of either metal is usually effected by a colorimetrical process—namely, by comparing the depth of colour produced by sulphuretted hydrogen in the water to be examined with that produced in a solution of lead of known strength, in precisely analogous manner as the colorimetrical determination of ammonia in water. The details are, therefore, evident to every one who is acquainted with this latter process, and need no description. The standard solution is prepared by dissolving a known quantity of crystals of pure acetate of lead.

Estimation of suspended matters.—A large quantity of the turbid water, say 1 litre, is filtered through a dried and weighed filter, which is then redried and again weighed. Thus the total suspended matter is obtained. It is subsequently incinerated in a weighed platinum crucible, and in this manner the proportion of mineral and organic suspended matter is arrived at. The substances in suspension are frequently so finely divided that they pass through the best filter paper, and sometimes they settle with such extreme slowness, that the estimation becomes practically impossible. A quantitative analysis of the mineral portion is seldom required, although it may be desirable in some cases to test it qualitatively. Again, when the sediment is thus collected a good opportunity is presented for a further microscopical examination.

CHAPTER IV.

TEA AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Leaves other than those of tea, except those used for scenting; exhausted tea-leaves and damaged tea; an undue proportion of stalks or vegetable matter foreign to tea, of any kind whatever; foreign mineral matter, especially sand, quartz, soapstone, China clay, magnetic oxide of iron, &c. Lastly, the substances used for artificially colouring or painting the teas, as ferrocyanide of iron, or Prussian blue, indigo, turmeric, &c.

Growth and Preparation.

The tea-plant, *Thea sinensis*, is a hardy evergreen flowering shrub, attaining the height of from three to six feet and upwards. It belongs to the natural family *Columniferæ*, *Ternstrœmiaceæ* of Lindley, which includes the camellias and myrtles. The tea-plant occurs indigenously or is specially cultivated in China, Japan, parts of India, especially the southern side of the Himalayas, and in Western Africa; but the plants will grow in many other mild climates, and it is stated that they will flourish in all latitudes from the equator up to 40°. It is usually propagated from seed; the seedlings when a year old are planted in rows, three or four feet apart. They come to maturity in three or four years, yielding in the course of the season three, and in some cases four, crops of leaves. When ten or twelve years old, the plants are dug up and replaced by other seedlings.

The first gathering takes place early in the spring, the second in the beginning of May, the third about the middle of June, and a fourth in August. The leaves of the first gathering are the most valuable, and from these Pekoe tea, which consists of the young leaves and leaf buds, as well as black teas of the highest quality, are prepared. The leaves of the last gathering are large and old, and inferior in flavour and value.

The use of tea became general in China about the year 600, but it was not until the seventeenth century that it was brought to Europe.

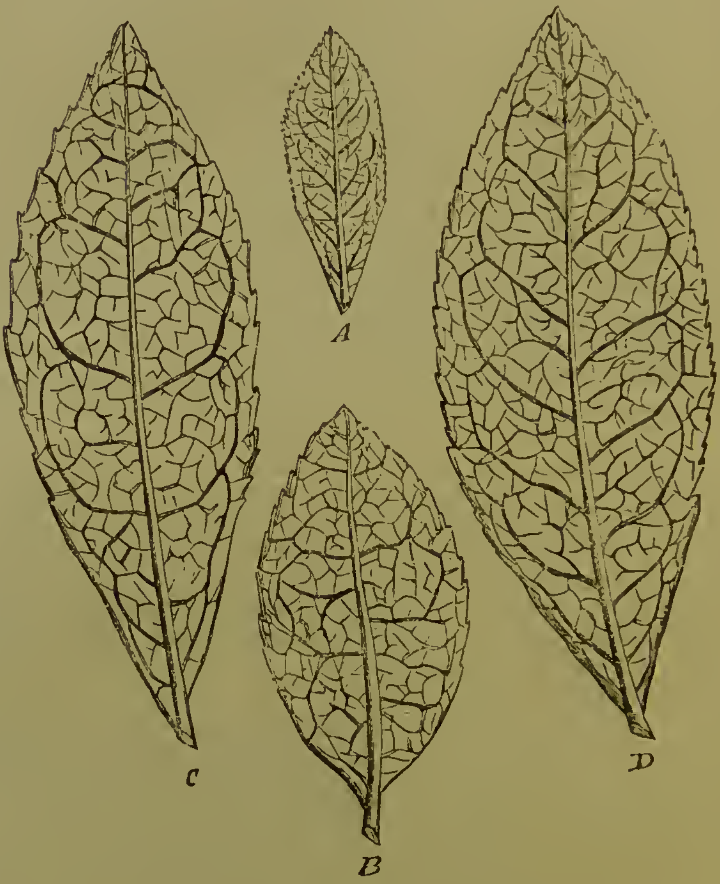
The teas of commerce are divided into black and green. All the varieties of these are derived from the same species of tea-plant, the differences depending upon soil, climate, age of the leaves, and mode of preparation. The plants from which black teas are prepared are grown chiefly on the slopes of hills and ledges of mountains, while the green teas are cultivated in manured soils; other differences between the two kinds of tea are occasioned by the processes adopted in the preparation and roasting of the leaves. Thus, the leaves of black tea are allowed to lie in heaps for ten or twelve hours, during which they undergo a species of fermentation, and it is this which occasions them to assume a dark colour They are then tossed about till they become flaccid. They now emit the characteristic odour of tea; the leaves are next rolled with the hands into balls on a wooden table, and much liquid is said to be expressed from them. 'After which they are shaken out, roasted for a few minutes, again rolled, and while still flaccid are exposed to the air for some hours upon shallow bamboo trays; this alternate heating and rolling is repeated three or four times, and finally the leaves are dried slowly over charcoal fires.' Those of green tea are not subjected to this preliminary fermentation, but are roasted 'within an hour or two after they have been gathered, in pans over a brisk wood fire. After four or five minutes' roasting the leaves become flaccid and are rolled by the hands upon a wooden table; they are then again thrown into the drying pans, where they are kept in rapid motion, and in about an hour and a half are completely dried' (Watts). But the leaves thus prepared are of a yellowish or olive-green tint, very unlike the colour of the painted green teas imported into this country from China.

The outward characters of certain teas depend upon the rolling to which the leaves are subjected, an operation which is three or four times repeated in the case of superior teas, before the drying and rolling are considered to be complete.

The Scenting of Tea.—To certain descriptions of tea an artificial odour or scent is imparted. This is communicated to the teas chiefly by means of the *Chulan* flower, *Chloranthus inconspicuus*; those of *Olea fragrans*, *Gardenia florida*, and *Jasminum sambac* are, however, also sometimes used for the purpose. Two processes are adopted for the scenting of the tea. In some cases the fresh flowers are strewn between successive layers of tea, and both are then roasted until the flowers become crisp, when they are sifted out. In others the flowers are dried, powdered, and then sprinkled over the tea.

The principal kinds of *black* tea are *Bohea*, the commonest description, *Congou*, *Souchong*, *Caper*, and *Pekoe*, which last is of the highest quality, consisting of the unexpanded leaves and buds, which, when clothed with hairs or down, constitute *Flowery Pekoe*; but the three last named teas really possess more the characters of green than of black teas. The chief varieties of *green* tea are *Twankay*, *Hyson Skin*, *Young Hyson*, *Hyson*, *Imperial*, and *Gunpowder*, this last corresponding in green tea with Flowery Pekoe. Imperial, Hyson and Young Hyson consist of the second and third gatherings, while the light and inferior leaves separated from Hyson by a winnowing machine constitute Hyson Skin, in much demand amongst the Americans. The *scented* teas are *Scented Caper*, or *Schulan*, and *Scented Orange Pekoe*. These teas are not drunk by themselves, but are usually mixed in small proportions with other teas. Indeed, there are few kinds of tea which are partaken of alone; nearly all the teas of the shops consisting of a mixture in various proportions of different kinds of tea, one being used for its flavour and fulness on the palate, another for its odour, and a third for its strength, colour, and body. Teas are, in fact, even more subject to the operation of blending than wine itself. This blending

Fig. 18.



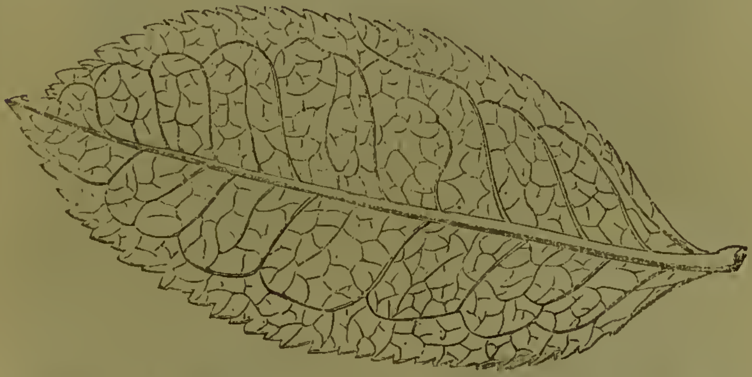
LEAVES OF THE TEA-PLANT.

A, Young leaf; *B*, leaf of black tea of medium size; *C*, ditto of larger growth; *D*, leaf of the green variety of the tea-plant.

or mixing constitutes a special art or business, and so particular are most large and wholesale firms, that they always keep portions of the first mixings to serve as standards or guides for the next mixing; uniformity of quality, so much desired by many customers, being thereby obtained.

The form of the leaves.—The leaves vary considerably in size and form, according to age. The youngest leaves are narrow, downy, and present slight evidences of serration. Those next in age and size have their edges delicately serrated, with the venation but little perceptible; in those of medium and large sizes the venation is well marked, a series of characteristic loops being formed along each margin of the leaves, the serrations being stronger and deeper and wider apart. Sometimes, as in the Assam variety of the tea-plant, the serrations are alternately large and small, a difference which is probably not constant.

Fig. 19.

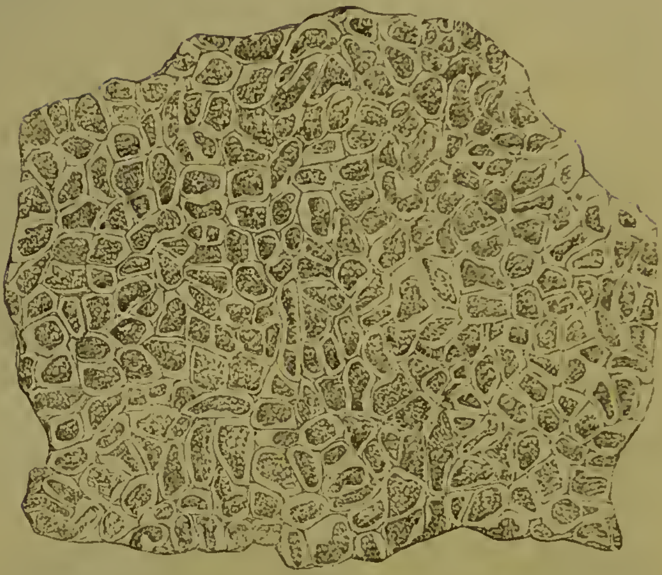


Leaf of the *Assam* variety of the TEA-PLANT; the venation is the same as in the black and green varieties, but there is a slight difference in the serrations, which are alternately large and small—a difference which is probably not constant.

The form, serration and venation of the tea-leaf are usually sufficiently characteristic to distinguish it from most other leaves with which tea is liable to be mixed, but in cases of doubt or difficulty most valuable aid is obtained by a knowledge of the minute structure of the leaf as shown by the microscope.

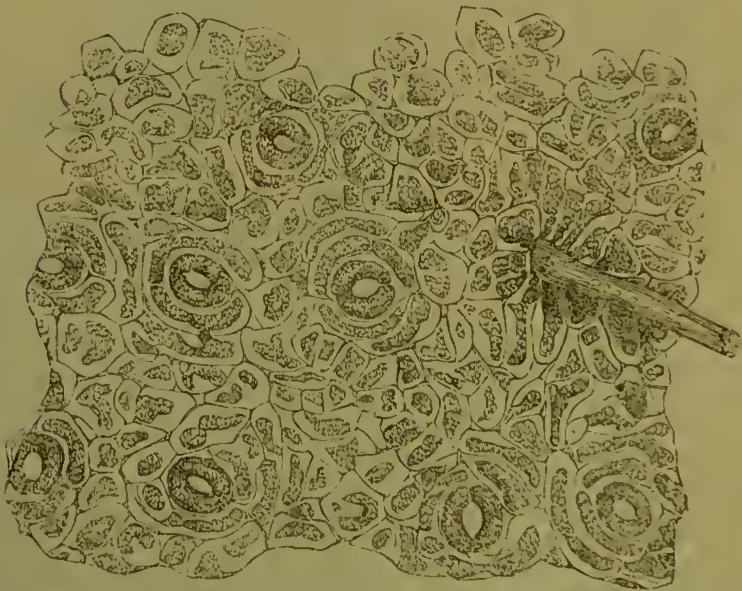
Minute structure of the tea-leaf.—The tea-leaf is made up of *epidermic* cells, *parenchimatous* cells, *stomata*, *hairs*, and *woody fibre*, the latter forming the basis or skeleton of the leaf. The *cells of the epidermis* vary in accordance with the size of the leaf; in that of medium size the cells are small and slightly angular only, while in the hard and old leaf they are larger, more angular, and the walls of the cells are more

Fig. 20.



Upper surface of TEA-LEAF, showing its structure. Magnified 350 diameters.

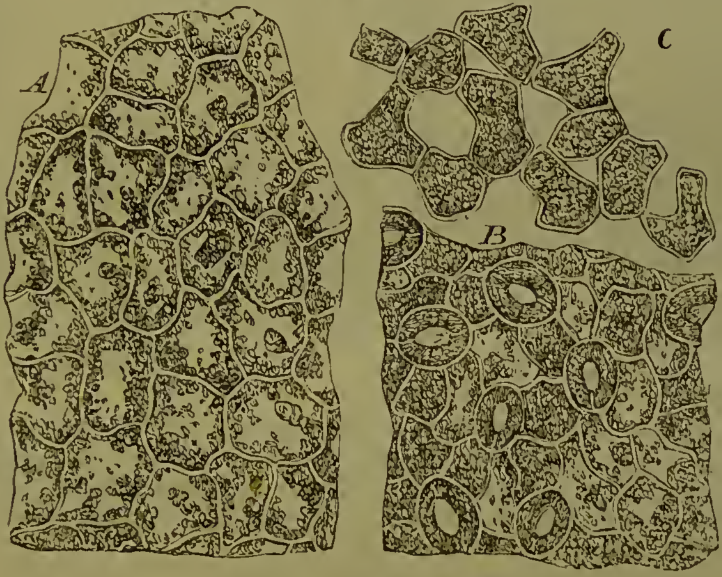
Fig. 21.



Under surface of TEA-LEAF, showing the stomata and cells of this portion of the leaf, as well as a part of one of the hairs by which this surface is clothed. Magnified 350 diameters.

distinctly visible. The *stomata* are confined to the under surface of the leaves, are rather numerous, oval, or sometimes nearly round, and formed of two reniform cells, which encircle a very apparent aperture. The *epidermic* cells, to adapt themselves to the form of the stomata, are themselves curved. The *hairs* are also confined to the under surface of the leaf. They are very numerous on young leaves, less abundant on those of middle age, and on old leaves are nearly altogether wanting. They are short, pointed, and undivided. The cells forming the *parenchyma* of the leaf resemble those of most other leaves, and do not present anything remarkable.

Fig. 22.



TEA-LEAF.

A, upper surface of fully-developed leaf, representing the cells of which it is constituted; *B*, under surface, showing its cells and stomata; *C*, chlorophylle cells.

COMPOSITION OF TEA.

The infusion made from tea contains *colouring matter*, *gum*, *saccharine matter* or *glucose*, *tannin*, a peculiar *volatile oil*, a *nitrogenous alkaloid* or principle called *Theine*, identical with caffeine, *albuminoid matter*, and various *organic* and *inorganic* salts; while that portion which is insoluble in hot water consists chiefly of the albuminoid matter, colouring matter, and cellulose, in the forms of cells and fibre.

A very good idea of the age and quality of a tea may be gathered from the relative proportions of matter, soluble and insoluble, in hot water. The following table exhibits the quantity of extractive matter furnished by samples of black and green teas of various qualities and descriptions:—

Quantity of Extractive Matter.

Black Teas.		Black Teas.	
Ankoi Congou	28·16	Ramoo broken	33·25
Pekoe Congou	26·23	Broken Orange Pekoe	40·99
Pekoe Souchong	24·63	Pekoe, Ramoo	42·25
Assam Souchong	37·76	Ramoo Pekoe Souchong	39·14
Pekoe Souchong	38·15	Black tea	33·25
Moning Congou	29·47	" "	28·24
Kaisou Congou	26·36	" "	25·34
Orange Pekoe	39·00	" "	25·14
Mixed Black	31·08	" "	28·76
" "	40·08	" "	32·79
Pure Black	40·00	" "	26·15
Mixed	41·58	" "	24·72
Moning Congou	37·66		
Java Souchong	47·40	Average	33·85
Assam broken	46·50		

Green Teas.		Green Teas.	
Pearl Gunpowder	27·70	Kumaon Young Hyson	46·50
Moyune Hyson	39·03	Green tea	39·06
Mixed Green	46·64	Foo Chow Caper	38·21
" "	41·36	Gunpowder	37·47
Pure Green	43·32	Green tea	35·68
Java Young Hyson	50·38		
" " "	45·88	Average	41·20
Japan Oolong	44·46		

According to Péligot, black tea furnishes an average extractive of 39·6 per leaf, and green tea of 42·9 per leaf. There is no doubt that Peligot's average for black tea is far too high, and this undoubtedly arises from the fact of his having included among his black teas a number of really green teas, as the Pekoes.

According to Mulder's analysis, 100 parts of tea consist of—

	Green	Black
Essential oil (to which the flavour is due)	0·79	0·60
Chlorophylle	2·22	1·84
Wax	0·28	—
Resin	2·22	3·64
Gum	8·56	7·28
Tannin	17·80	12·88
Theine	0·43	0·46
Extractive	22·80	19·88
Dark extractive deposit	—	1·48
Coloured matter, separable by hydrochloric acid	23·60	19·12
Albumen	3·00	2·80
Vegetable fibre	17·08	28·32
Ash	5·56	5·24
	104·34	104·04

Moleschott gives the following mean analysis of black tea, compiled from the analyses of Mulder, Warrington, Stenhouse and Peligot:—

Theine	1·576
Albumen	2·375
Dextrin	8·668
Cellulose	20·077
Wax	0·130
Chlorophylle	1·901
Resin	2·203
Tannic acid	13·969
Ethereal oil	0·669
Extractive matters	18·410
Apothema	0·690
Ash	4·808
Water	6·500
	81·976

The albumen or legumin is obviously greatly underrated in the above analysis, and the figures given, as will be seen, do not make up a hundred parts, although doubtless the analysis represents the percentage composition of tea. It is not quite clear what has been omitted, unless it be the coloured matter of Mulder, separable by hydrochloric acid, and which probably consisted in the main of albuminous matter.

Analyses recently made by the author furnished the following results:—

	Black	Green
Water	11·56	9.37
Tannin	15·24	18·69
Gum	5·70	5·89
Albuminous matter	15·55	24·39
Theine	2·53	2·79
Ash	5·82	5·38
Chlorophylle and other undetermined extractive matter	5·24	1·83
Matter insoluble in water; cellulose, &c., minus albuminous matter	38·36	31·66
	100·00	100·00
Total extractive matter	33·25	39·06
Nitrogen in the insoluble	1·82	2·48
Nitrogen in the soluble	1·38	2·07
Total nitrogen	3·20	4·55
Parts of ash soluble in water	62·69	68·05
Insoluble in water	37·31	31·95
	100·00	100·00

The following quantities of *nitrogen* have been found in tea by different chemists. Peligot obtained in Pekoe tea, dried at 100° C., 6·58 per cent.; in Gunpowder 6·15, in Souchong 6·15, and Assam 6·10. The aqueous extract of dried Gunpowder tea yielded 4·3, of green Souchong 4·7 per cent., while the exhausted leaves furnished 4·6 per cent. for the Souchong, and 4·4 per cent. for the Gunpowder. These quantities appear to be too high.

We obtained from a sample of black tea, not previously dried, as will be seen by our analyses, 3·20 per cent., and from green tea 4·55 per cent.

Theine, when pure, crystallises in fine needles of a silky lustre. They lose at 100° C. one atom of water of crystallisation, amounting to about 8 per cent. of their weight. They are bitter and have no smell; they melt at 178° C. and sublime at 185° C., without decomposing. It is freely soluble in boiling water, and less soluble in ether and alcohol; in 93 parts of water of ordinary temperature and in 300 parts of ether, according to Péligot. The crystals which separate from the ethereal solution are anhydrous. When heated with soda lime it yields cyanides. Theine is a feeble base, and is precipitable by tannin from its solutions; its formula is $C_8H_{10}N_4O_2$, according to which it contains 28·87 per cent. of nitrogen.

The theine in Mulder's analyses is obviously much underrated. Stenhouse gives in the teas of commerce an average of 1·39 per cent. based upon 8 analyses, while our average, founded upon 25 determinations, amounts to 2·1; but Péligot obtained much larger quantities: in Hyson 2·4 and 2·56 per cent.; in a mixture of equal parts of Gunpowder, Kaisou, Caper and Kaisow tea, 2·7; in Gunpowder tea 3·5 and 4·1 per cent., and even 6·21 per cent., of which 3·84 per cent. crystallised out from the concentrated solution, and 2·37 were obtained by precipitation with tannic acid. Many of these numbers are obviously too high, and Péligot must have obtained, one would suppose, the theine in an impure state.

The quantities, however, present in tea, as will be seen by the following table, vary greatly; but, as a rule, green teas contain more than black. It does not appear that any strict relation exists between the amount of theine present and the quality of tea.

Quantities of Theine in Genuine Teas.

	Black		Black
Ankoi Congou	1·57	Mixed	1·58
Pekoe Congou	3·04	Assam broken	1·66
Pekoe Souchong	2·13	Ramoo broken	1·93
Assam Souchong	1·36	Broken Orange Pekoe	2·05
Pekoe Souchong	1·61	Kumaon Young Hyson	2·37
Moning Congou	1·83	Ramoo Pekoe	2·80
Kaisou Congou	2·31	Ramoo Pekoe Souchong	2·29
Orange Pekoe	1·90	Black tea	2·53
Mixed Black	2·08		
„ „	2·73	Average	2·08
Pure Black	1·74		

	Green		Green
Pearl Gunpowder	1·61	Foo Chow Caper	2·59
Moyune Hyson	2·59	Green tea	2·79
Mixed Green	1·08		
,, ,,	2·35	Average	2·17%

The *volatile oil* is not present in fresh tea, but is developed in the course of drying and roasting. It is of a lemon colour, readily solidifies, and becomes resinous on exposure to the air. It is to it that the aroma is mainly due. The amount present in tea is stated to be about 1 per cent., a statement we consider to be open to much doubt.

The ash of tea.—The question of the quantity and composition of the ash of tea possesses considerable importance in relation to the age, quality, and purity of the tea. We will first refer to the weight of the ash of genuine tea, both black and green. To determine this point we have made numerous observations, a few of which we here introduce:—

Genuine Black Tea.

Broken leaf	5·34	Scented Orange Pekoe	5·78
Congou	5·23	Black tea	5·76
Assam broken	5·86	,, ,,	6·10
Java Souchong	5·63	Assam	5·07
Moning Congou	6·03	Congou	5·83
Black tea	6·03	,,	5·70
,, ,,	6·05	Black tea	5·82
,, ,,	5·96	Broken leaf	6·06
Ankoi Congou	5·63	,, ,,	5·50
Pekoe Congou	5·43	Ramoo Pekoe Souchong	5·24
Assam Souchong	6·10	Ramoo Pekoe	5·72
Pekoe Souchong	5·70		
Moning Congou	6·71	Average	5·78
Kaisou Congou	6·46		

Unfaced Green Tea.

Pearl Gunpowder	5·86	Japan Oolong	5·78
Moyune Hyson	6·30	Java Young Hyson	5·90
Hyson	5·24	,, ,, ,,	5·61
Green tea	6·42	Green tea	5·40
Uncoloured China tea	5·13		
Oolong	5·93	Average	5·75
Kumaon Young Hyson	5·66		

From these determinations it appears that the lowest ash met with in black tea was 5·23 and the highest 6·71 per cent., and the mean of all 5·78; while in green teas the ash ranged from 5·13 per cent. to 6·42 per cent., the mean being 5·75. It will be seen that a few of the samples furnished ashes exceptionally high, and it is quite possible that in these cases a little extraneous matter may have found its way into the teas, but we have thought it best not to exclude them from the tables. Perhaps, after all, a more certain datum of the genuineness of the tea than the ash would be the amount of extraneous silica which it contains.

It is of consequence to notice that the ashes of genuine and pure teas are entirely non-magnetic. It will be seen from the following tables that the quantities of iron and extraneous silica in genuine black and green teas vary considerably, the average of the iron being 0·12 and of the silica 0·51 in the black, while in the green teas the averages are 0·16 and 0·41. In the faced green teas it is curious to observe that the average percentage of iron is so little increased, but the amount of silica is augmented to the extent of one-third.

Genuine Black Teas.

Name.	Ash.	Silica.	Iron.
Black	5·82	0·33	0·17
Broken leaf . . .	6·06	0·28	0·14
" " . . .	5·50	0·18	0·12
Ramoo Pekoe Souchong .	5·24	0·59	0·09
Ramoo Pekoe . . .	5·72	0·67	0·12
Ramoo broken Orange Pekoe	5·70	0·66	0·08
Ramoo broken leaf . .	5·65	0·74	0·11
Moning Congou . .	5·06	0·74	0·17
Canton Orange Pekoe .	5·75	0·43	0·10
Average . .	5·61	0·51	0·12

Omitting the four samples of Ramoo or Indian teas, the average percentage of silica in the Chinese teas amounts to only 0·30 per cent.

Unfaced Green Teas.

Name.	Ash.	Silica.	Iron.
Green	6·42	0·37	0·21
Uncoloured China . .	5·13	0·14	0·11
Oolong	5·93	0·77	0·24
Kumaon Young Hyson .	5·66	0·36	0·10
Japan Oolong . . .	5·78	—	—
Java Young Hyson . .	5·90	—	—
Ditto	5·61	—	—
Green	5·40	—	—
	5·73	0·41	0·16

It will thus be seen that the ash of uncoloured green teas corresponds closely in weight and in the amount of iron present with that of genuine black tea. If the Oolong be omitted, the iron and extraneous silica are rather less than in black tea.

It appears from the analyses of Zöller, reported in 'Liebig's Annalen,' that the age of tea-leaves may be determined from the analysis of the ash—a fact of much interest and of considerable value. Thus young leaves, of which the best teas consist, contain much larger amounts of potash and phosphoric acid than the older leaves, which are comparatively deficient therein, while they become richer with age in lime and silica.

Much potash and phosphoric acid, with little lime and silica, indicate, therefore, good tea; the reverse bad tea. The ash of a sample of young tea grown in the Himalayas amounted to 5·63 grains per cent., and it contained in 100 parts 39·22 of potash, 4·24 of lime, 4·38 of oxide of iron, 4·35 of silica, and 14·55 of phosphoric acid. From the same sample of tea 4·94 per cent. of theine were obtained, and 13·7 of proteine compounds.

The following table of the analysis of the tea ash is from 'Watts's Dictionary:'—

	Souchong. Spooner.	Souchong. Spooner.	Oolong. Tevis.	Young Hyson. Hague.	Ning Young. Homer.	Dry aqueous extract. Lehmann.	Himalaya tea. Zöller.	Spent leaves. Zöller.
Soda . . .	25·46	1·70	40·00	9·26	12·88	5·03	0·65	0·69
Potash . . .	3·70	44.96	12·38	33·95	28·38	47·45	39·22	7·34
Magnesia . .	9·59	8·41	6·17	6·79	—	6·84	6·47	11·45
Lime . . .	11·36	8·77	7·68	8·17	8·39	1·21	4·24	10·76
Oxide of iron .	8·42	6·80	7·18	4·75	19·31	3·29	4·38	9·53
Oxide of manganese	—	—	—	—	—	0·71	1·03	1·97
Phosphoric acid .	12·62	11·46	8·26	16·64	17·44	9·88	14·55	25·41
Sulphuric acid .	10·14	6·96	8·27	4·89	4·76	8·72	trace	trace
Silicic acid . .	16·04	8·79	7·81	10·89	5·59	2·31	4·35	7·57
Carbonic acid .	—	—	—	—	—	10·09	24·30	25·28
Chloride of sodium.	2·40	2·15	2·25	4·66	3·25	3·62	0·81 chlorine	} trace
	99·73	100·00	100·00	100·00	100·00	99·18	100·00	100·00
Ash per cent of dry substance . .	5·48	6·11	5·14	5·94	4·73	19·69	—	—

It will be seen that Lehmann gives manganese as a constituent of the ash; this, like iron, is of constant occurrence. Fleitman, in an infusion of 70 grammes of Pekoe tea, is stated to have met with as much as 0·20 gramme of manganous oxide, but this quantity is evidently excessive.

THE PROPERTIES OF TEA.

Tea owes its properties mainly to the *tannin*, the *theine*, and the *volatile oil*. The first gives it astringency; the second stimulates both the vascular and nervous systems, and subsequently produces narcotic effects; while the third not only acts as a stimulant, but imparts the aroma, which is so characteristic of good tea and which is so grateful to many. Tea exerts its power chiefly on the nervous system. It excites the activity of the brain and stimulates the flow of thought; but in excess produces sleeplessness, anxiety, trembling, and sometimes even spasm. It increases a little the action of the heart, and also the insensible perspiration. The pulmonary carbonic acid is also, according to E. Smith, increased, but the question as to whether the urea is augmented or diminished appears as yet undecided. The common belief is that it is decreased. Liebig and Lehmann both found it to be increased, but Böker, on the other hand, states that it is diminished.

Pereira, in his 'Materia Medica,' remarks: 'Another quality possessed especially by green tea is that of diminishing the tendency to sleep. Tea appears to possess a sedative influence with regard to the vascular system. Strong green tea taken in large quantities is capable in some constitutions of producing most distressing feelings, and of operating as a narcotic.'

Professor Johnston writes: 'It exhilarates without sensibly intoxicating. It excites the brain to increased activity, and produces wakefulness. Hence its usefulness to hard students; to those who have vigils to keep, and to persons who have to labour much with the head. It soothes, on the contrary, and stills the vascular system, and hence its use in inflammatory diseases and as a cure for headache. Green tea when taken strong acts very powerfully upon some constitutions, producing nervous tremblings and other distressing symptoms, acting as a narcotic, and in inferior animals even producing paralysis. Its exciting effect upon the nerves makes it useful in counteracting the effects of opium and of fermented liquors, and the stupor sometimes induced by fever.'

With reference to the action of the *volatile oil* Prof. Johnston observes: 'That it does exert a powerful, and most likely a narcotic, influence is rendered probable by many known facts. Among them I mention the headaches and giddiness to which tea-tasters are subject: the attacks of paralysis to which after a few years those who are employed in packing and unpacking chests of tea are found to be liable, and the circumstance already alluded to, that in China tea is rarely used till it is a year old, because of the peculiar intoxicating property which new tea possesses. The effect of this keeping upon tea must be chiefly to allow a portion of the volatile ingredients of the leaf to escape. And, lastly, that there is a powerful virtue in this oil is rendered probable by the fact that the similar oil of coffee has been found by experiment to possess narcotic properties.'

The operation of the second active constituent of tea, *Theine*, has been determined by experiment. In the quantity in which it is daily consumed by most tea-drinkers—that is to say, some four or five grains, ordinarily present in about half an ounce of good tea—it has been found to diminish the waste of tissue, the necessity for food to repair the waste being lessened in an equal proportion; one of the effects of tea is therefore to save food.

If an ounce of tea of good quality be daily partaken of, which would contain from 8 to 10 grains of theine, the pulse is rendered more frequent, the action of the heart stronger, trembling ensues, and there is a perpetual inclination to micturition. 'At the same time the imagination is excited, and after awhile the thoughts wander, visions begin to be seen, and a peculiar state of intoxication comes on. All these symptoms are followed by and pass off in deep sleep.'

It is evident, therefore, that the effects of strong tea are attributable, in a great measure, to the theine therein contained.

The third active principle of tea, the *tannin* or tannic acid, causes the infusion to exert a slightly constipating effect upon the bowels.

A fourth not unimportant constituent of the tea-leaf is *gluten*, which sometimes forms no less than one-fourth of the weight of the dried leaf. Zöller found in a sample which he tested 13·7 per cent. of gluten, while we have obtained from 15·5 in black to 24·4 in green tea.

As tea is consumed in this country the benefit of the gluten is in most cases lost, since it is not dissolved by the hot water, but remains in the leaves, with which it is thrown away; but if soda be used, much of the gluten is dissolved and will then be consumed with the infusion. In some countries the tea-leaves from which the infusion has been made are themselves eaten, and in this way the whole of the properties of the tea are secured. Amongst the Japanese the leaves are ground to powder and drank with the infusion. The more wealthy Chinese simply infuse the leaves in a porcelain cup, furnished with a cover; the leaves for the most part sink to the bottom of the cup, but occasionally a few float and rise to the surface. To prevent this inconvenience a thin piece of silver filagree-work is sometimes placed upon the leaves.

It appears that in China, tea is the common beverage of the people. The late Sir George Staunton informs us 'that tea, like beer in England, is sold in public houses in every town and along public roads, and the banks of rivers and canals; nor is it unusual for the burdened and weary traveller to lay down his load, refresh himself with a cup of warm tea, and then pursue his journey.'

Lo-Yu, a learned Chinese, who lived in the dynasty of Tang, A.D. 618 to 906, gives the following agreeable account of the qualities and effects of the infusion of the leaves of the tea-plant:—'It tempers the spirits and harmonizes the mind; dispels lassitude and relieves fatigue; awakens thought and prevents drowsiness, lightens or refreshes the body, and clears the perceptive faculties.'

THE ANALYSIS OF TEA.

It has already been stated that the chief constituents of tea consist of chlorophylle, gum, glucose, gluten, cellulose, tannin, theine, volatile oil and mineral matter.

For the purpose of estimating the *soluble constituents* of tea, the leaves must be thoroughly exhausted by boiling with repeated quantities of distilled water until the infusion is no longer coloured and ceases to yield on evaporation any solid residue. The different infusions thus obtained are mixed together and reduced by evaporation to a certain bulk. One portion is evaporated with magnesia to dryness on the water bath, the magnesia being used to neutralise the tannic acid and to set the theine free; and in this the theine is estimated in the manner to be hereafter described.

Another quantity of the infusion is mixed with spirits of wine, to precipitate the gum, while a third quantity is taken for the estimation of the tannin.

The *insoluble portion* of the leaves is dried and weighed; the difference in the weight as compared with the original quantity taken gives the proportion of the constituents soluble in water.

For the determination of the *nitrogenous matter,* sometimes termed Legumin, a separate portion of tea must be taken, and a combustion analysis for nitrogen made, the amount of nitrogen present in the theine being deducted from the total amount obtained. The remaining nitrogen, multiplied by 6·33, gives the proportion of nitrogenous matter or gluten.

The usual soda-lime process does not furnish the whole amount of nitrogen, since the theine yields, on heating with alkalies, some cyanide, which of course would not be obtained as ammonia. The oxide of copper combustion, although exact, involves a very great deal of trouble and labour. We give the following outlines of the process:—

0·2 to 0·5 gramme of tea are mixed intimately with recently ignited oxide of copper. A combustion tube, drawn out in the usual way, is first charged for the length of 4 inches with a mixture of bicarbonate of soda and of bichromate of potash, then with a few inches of pure oxide of copper, then with the mixture containing the tea, then with another layer of pure oxide of copper, and lastly with a spiral of metallic copper. The air contained in the tube is first driven out by heating the layer of bicarbonate of soda, and thus generating carbonic acid. The gases produced by the combustion of the tea-mixture are collected over mercury, freed from carbonic acid by means of caustic-potash solution, and the nitrogen is measured, attention of course being paid to the temperature, pressure of the air, and the moisture of the gas; for all of which circumstances tables have been specially prepared.

For the estimation of the *water* and the *ash* a separate portion must be taken; the tea should be dried on a water bath; the loss represents the water; the residue is incinerated and the ash weighed.

For the estimation of the *volatile oil* a considerable quantity of tea must be operated upon. This must be distilled with water and the distillate received into a cool receiver; the oil should be found floating on the surface of the water. We may state, however, that, in certain attempts we have made, we have failed to obtain any weighable amount of the oil; the distillate had the odour of tea, but no oil drops were visible. Such is a brief outline of the processes to be adopted in the analysis of tea. The estimation of the sugar and chlorophylle are exceedingly difficult, the tannin decomposing into sugar and gallic acid, and hence reducing the copper solution in the same manner as sugar. They are seldom if ever required, and therefore it is unnecessary to give any details respecting their determination.

To resume. For the infusion from which the theine, gum and tannin are to be estimated take five grammes of tea; for the combustion half a gramme, and for the estimation of water and ash three grammes.

Of the infusion of the five grammes reduced to a bulk of 500 cc., 300 cc. are used for the estimation of the theine, 100 cc. for the gum, and the last 100 cc. for the tannin.

The estimation of the Theine.—The theine may be conveniently and simply estimated by Mulder's process, which is thus carried out: The 300 cc. of the solution are to be evaporated, with the addition of some magnesia, to dryness; the residue is then finely powdered and transferred to a flask, capable of holding about 200 cc.; 30 cc. of ether are poured over it, and allowed to digest for two days, with occasional shaking. The ether is then heated to boiling and poured into a small weighed flask. The residue is heated two or three times with successive quantities of ether, until this on evaporation ceases to furnish any crystalline deposit of theine. These several quantities are added to the first quantity of ether employed, and the whole is evaporated on the water-bath to dryness. The theine is left in a crystalline condition, and is then weighed together with the flask.

The difficulty of the solubility of theine in ether has suggested to Mr. Otto Hehner a modification of this process. In this absolute alcohol is used as a solvent, theine being much more soluble in this menstruum. The alcohol by boiling extracts not only all the theine, but a small quantity of other substances which are to be thus removed. The alcoholic solution is evaporated on the water bath to a few drops and ether is added; this precipitates the foreign substances, but does not now throw down the theine, since it is already in a state of solution. The ethereal solution is evaporated and the theine in the manner described above. Of course, it is necessary to thoroughly exhaust the extractive matter by treatment with two or three successive quantities of alcohol.

Another method, but one involving more time and trouble, is the following, as proposed by Péligot. The tea is exhausted with boiling water, and subacetate of lead is added in excess to the solution to precipitate the tannin, gum, and colouring matter. The mixture is boiled for some time, filtered, and the precipitate carefully washed on the filter with boiling water. The filtrate is freed from lead by a current of sulphuretted hydrogen, and after a second filtration evaporated at a gentle heat. It yields, on cooling, a crop of crystals of nearly pure theine, containing one molecule of water of crystallisation; an additional quantity being obtained by concentrating the mother liquor and leaving it to crystallise. The theine thus obtained is, however, less pure than that separated by the first process, and, moreover, a portion still remains in the mother liquor. These objections may be obviated by evaporating the watery solution to dryness and boiling with a sufficient quantity of ether. But this, of course, adds much to the time and trouble involved.

Stenhouse has recommended for the estimation of theine the process of sublimation, this alkaloid being volatile. The dried and powdered extract is subjected to heat, and the theine becomes deposited in a paper cone placed over it; we believe, however, that it is not possible to obtain the whole of the theine present by this procedure.

Estimation of Tannin.—The tannin may be estimated by one or other of the following processes. It may be precipitated by means of a titrated solution of gelatine and alum, as recommended by Müller, from the aqueous solution of the tea evaporated to a certain standard. One cc. of the gelatine solution should correspond to 0·01 gramme of tannin. Or the quantity of tannin may be determined by the weight of the precipitate, 100 parts of which contain 40 parts of tannin. Neither of these processes furnishes very exact results.

Mr. Allen recently proposed in the *Chemical News* a method for the estimation of tannin in tea by means of a solution of acetate of lead, using as indicator an ammoniacal solution of ferricyanide of potassium. Five grammes of acetate of lead are dissolved in 1 litre of water, and the exact strength of the solution is determined by means of a standard solution of tannin. Two grammes of tea are exhausted with boiling water, and the infusion is made up to 250 cc. Ten cc. of the standard lead solution are measured into a beaker, and diluted with 90 cc. of water. The tea infusion is added from a burette as long as any precipitate is thrown down; a small portion is filtered and tested with a drop of a weak ammoniacal ferricyanide solution. A red coloration indicates that all the lead is precipitated, and that tannin is in solution. From the volume of lead solution used the quantity of tannin is calculated.

Another method, which has the advantage of being easy and quick of execution if a great number of estimations are to be made, has been proposed by Löwenthal. We give it in its modified and improved form as described by Neubauer, 'Zeitschrift für Analytische Chemie,' X. It is based upon the fact that tannic acid is destroyed by the action of a solution of permanganate of potash, a solution of indigo being at the same time employed to indicate by its decolorisation the oxidation of the last trace of tannic acid.

The following are the solutions required for the execution of the method:—

1. A Solution of Sulphate of Indigo. 30 grammes of pure sulphate of indigo are dissolved in distilled water, the solution is filtered, and diluted to 1 litre. This solution decomposes very easily by the action of a peculiar fungus; it is best therefore to heat the solution in closed bottles in the water-bath to about 70° C, by which operation the germs of the fungus are destroyed, and the liquid keeps an indefinite period of time. The indigo must be very pure, and ought not to contain any indigo-red.

2. A Solution of Pure Tannic Acid. Two grammes of tannin of the purest description, dried at 100° C., are dissolved in 1 litre of water. The tannin must be perfectly white, and if possible chemically pure. If it cannot be obtained in a state of purity, the following method will be found to be convenient for the estimation of its strength:—Three grammes of the dried substance are dissolved in 250 cc. of water. The specific gravity of this solution is estimated at 15° C. by means of a specific gravity bottle. Tables have been constructed for the solutions of tannin of different strength, one of which will be found in Fresenius' 'Quantitative Analysis.' From these tables the quantity of tannin is obtained. 150 cc. of the solution are now to be freed from tannin by the action of well-washed, dried and powdered skin. The specific gravity of the liquid after this treatment is then taken, the tables again consulted, and the quantity of tannin corresponding to this second specific gravity is subtracted from the amount obtained from the first specific gravity. Supposing we find in the 250 cc. 2·93 grammes of pure tannin, then the crude tannin employed contains 97·33 per cent. of pure tannin.

3. A Solution of Permanganate of Potash, of such strength that 20 cc. of the solution of indigo require from 12 to 14 cc. of the permanganate, and 10 cc. of the standard tannin solution containing 0.2 per cent. of tannin, require from 9 to 10 cc. A solution of such strength is obtained by dissolving 10 grammes of pure crystallised permanganate of potash in 6 litres of water.

4. Dilute Sulphuric Acid.

The operation of the method is as follows:—20 cc. of the indigo solution are diluted with ¾ litre of distilled water, 10 cc. of dilute sulphuric acid are then added, and the beaker containing the blue liquid is placed upon a white sheet of paper. The permanganate solution is now added from a Gay-Lussac burette drop after drop, with constant vigorous stirring of the liquid. The deep blue colour of the solution is changed into dark green, which soon turns into light green, and afterwards yellowish green. A drop or two more of the permanganate solution cause the appearance of a bright golden yellow colour, when the reaction is finished, and the volume of the permanganate used is read off. 20

cc. of the indigo are then diluted exactly as before to $\frac{3}{4}$ of a litre; and, moreover, 10 cc. of the standard tannin solution are added. As above described, the permanganate solution is dropped into the liquid until the golden yellow colour appears. From the number of cc. used, the quantity of permanganate required for the oxidation of the 20 cc. of indigo solution is subtracted, and thus the amount of permanganate is obtained which is necessary for the oxidation of 10 cc. of the standard tannin solution. The strength of the permanganate solution is thus known, and of the infusion of the tea, obtained by exhausting 2 grammes with successive quantities of hot water, and bringing the solution up to 500 cc.; 50 cc. are titrated with the addition of 20 cc. of indigo as above described. From the quantity of permanganate solution used, the amount of tannin in the 50 cc. of tea infusion, and therefore in the 2 grammes of tea, is calculated by a simple rule of three sum.

There is no doubt that other substances besides the tannin are acted upon by the permanganate. Neubauer, therefore, removes the tannin and the gallic acid from a measured quantity of the infusion, by means of animal charcoal, and estimates the number of cc. of permanganate required for the oxidation of the remaining substances, which he subtracts from the total amount of permanganate used in the first experiment. Thus the exact quantity of tannin and gallic acid is obtained, indicating the total astringency.

Mr. Estcourt was the first to employ Löwenthal's method for the estimation of tannin in tea. He estimates the total astringency as above described; precipitates from another portion of the infusion the tannin by means of a solution of gelatine added slightly in excess; filters, and titrates the gallic acid in the filtrate with permanganate and indigo.

Estimation of Gum.—The gum may be estimated from the aqueous solution evaporated to the consistency of a syrup, and treated with strong alcohol. The gum is dried and weighed, and afterwards burned and the ash deducted, a precaution of importance and one usually neglected.

Estimation of Cellulose.—Two grammes of the tea are exhausted, first with boiling water, then with a one per cent. solution of soda, and lastly with an equally dilute solution of hydrochloric acid. The cellulose thus left is dried, weighed, and afterwards incinerated. The ash, if any be found, is to be subtracted.

Analysis of the Ash.—It is unnecessary to describe in this place all the various processes requisite for the full analysis of the ash; the details, if given, would apply to the analysis of the ashes of all other plants, and the methods of procedure are well known to chemists. We shall confine ourselves, therefore, to the determination of the phosphoric acid, potash, iron, and extraneous silica, all points of importance in connection with the question of the quality and purity of tea.

Estimation of Phosphoric Acid.—For the estimation of the phosphoric acid 3 grammes of tea are incinerated, and the ash is dissolved in nitric acid. The solution is evaporated to dryness on the water-bath to separate the silica naturally present in the ash. The residue is moistened with nitric acid, dissolved in boiling water and filtered. The filtrate is evaporated to a small bulk, and the phosphoric acid precipitated with a solution of molybdate of ammonia. A yellow compound, phosphomolybdate of ammonia, soon separates, especially on gently heating the liquid. This precipitate is filtered after standing twelve hours and dissolved in ammonia. To the ammoniacal solution is added chloride of magnesium, which combines with the phosphoric acid, forming phosphate of ammonia and magnesia, which is separated by filtration, burnt and weighed. 100 parts of this precipitate contain 63·96 parts of phosphoric anhydride, P_2O_5.

Estimation of Potash.—For the purpose of estimating the potash another 3 grammes of tea are incinerated. The ash is boiled with water and the watery solution filtered. The phosphoric acid is then removed by the addition of some lime water. The liquid is again filtered, and ammonia, carbonate of ammonia, and oxalate of ammonia are added in excess. After filtration the liquid is acidulated with hydrochloric acid, evaporated to dryness, and heated to incipient redness. Moisten again with water, filter, evaporate to a small bulk, and precipitate with a strong solution of chloride of platinum, which, combining with the chloride of potassium, forms potassio-platinic chloride, which is filtered through a weighed filter, dried and weighed. 100 parts of this precipitate correspond to 19·272 parts of potassa, K_2O.

Estimation of Silica.—For the estimation of the iron and extraneous silica, the following simple method is conveniently employed. The ash of 5 grammes of tea is boiled with strong hydrochloric acid, which dissolves all but the extraneous silica, which is collected on a filter, washed and weighed.

Estimation of Iron.—The filtrate containing the iron in solution, partly as ferric, partly as ferrous chloride, is heated to boiling, and mixed with a dilute solution of stannous chloride, which reduces all iron to the ferrous state. The completion of the reduction is pretty accurately indicated by the liquid becoming colourless. A solution of bichloride of mercury is added, to remove the excess of the stannous chloride. A standard solution of bichromate of potash is now gradually added from a burette divided into tenths of a cubic centimetre. Successive drops of the liquid are taken out with a glass rod, and placed on a porcelain dish in contact with a small drop of ferricyanide of potassium; as long as there is any iron in the ferrous state a blue coloration of ferrous ferricyanide will be produced. As soon as this coloration ceases to appear, the reaction is at an end; the volume of the bichromate solution is read off, from which the quantity of the iron present is calculated. A solution of bichromate of potassium, containing in 1,000 cc. 1·4759 gramme, is of such strength that 1 cc. of it is capable of oxidising 0·00168 gramme of iron.

A more detailed description of the processes above given will be found in Fresenius' work on 'Quantitative Analysis.'

A deduction of 0·5 per cent. of silica and of 0·15 per cent. of iron has to be made from the amounts of these substances found these figures representing the averages of silica and iron present, in genuine teas based upon the examination of numerous samples. Zöller found in the ash of genuine tea that the ferric oxide amounted to 4·38 of the ash, while Liebig found 3·29 per cent.

THE ADULTERATION OF TEA.

Formerly tea was extensively adulterated in this country, but in consequence of the gradual reduction of the duty, this practice has now nearly ceased. The adulterations resorted to were in principle similar to and in imitation of those so ingeniously designed by the Chinese themselves, as will be seen hereafter.

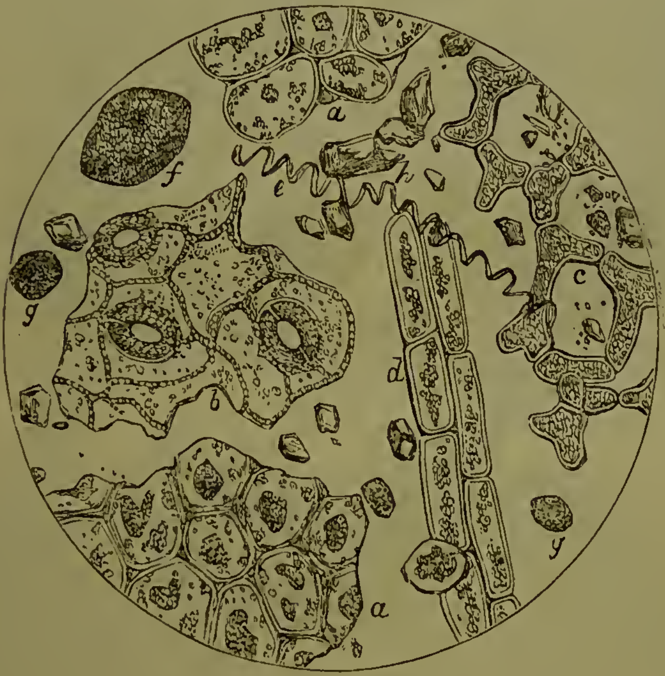
The *adulterations resorted to by the Chinese* may be described under the four following heads:—

1. With foreign leaves.
2. With lie-tea.
3. With mineral substances.
4. With materials used for the coloration, painting, or facing of tea.

I. *With foreign leaves.*—It will be a satisfaction to learn that the great bulk of the ordinary black teas, the Congous and Souchongs, consumed in this country are free from admixture with foreign leaves and all other adulteration. The foreign leaves, when employed, are found principally in very low-priced and much broken teas, and in the lower qualities of black and green gunpowder teas; in Twankay tea, and especially in an article, to be described hereafter, extensively employed for the adulteration of tea, and very candidly designated by the Chinese themselves 'Lie-tea.' Still, although the bulk of the black teas is genuine, yet many samples are to be met with, from time to time, containing an admixture of leaves other than those of the tea-plant. We have ourselves, in an experience extending over many years, met with a not inconsiderable number of such samples; the foreign leaves, however, rarely form more than a small proportion of the bulk of the article. Dr. Dixon, writing many years since in the 'Penny Cyclopædia,' states: 'The Chinese annually dry many millions of pounds of the leaves of different plants to mingle with the genuine, as those of the *ash*, *plum*, &c.; so that all spurious leaves found in parcels of bad tea must not be supposed to be introduced into them by dealers in this country. While the tea trade was entirely in the hands of the East India Company, few of these adulterated teas were shipped for this country, as experienced and competent inspectors were kept at Canton to prevent the exportation of such in the Company's ships; but since the trade has been opened all kinds find a ready outlet; and as the demand for tea exceeds the supply, a manufactured article is furnished to the rival crews.'

The teas, therefore, in which foreign leaves are liable to be met with are Congou and Souchong, but especially Twankay, gunpowder, caper, and lie-tea, which last is made up in imitation of these and other descriptions of tea, and is often used to adulterate the ordinary black teas of commerce.

Fig. 23.

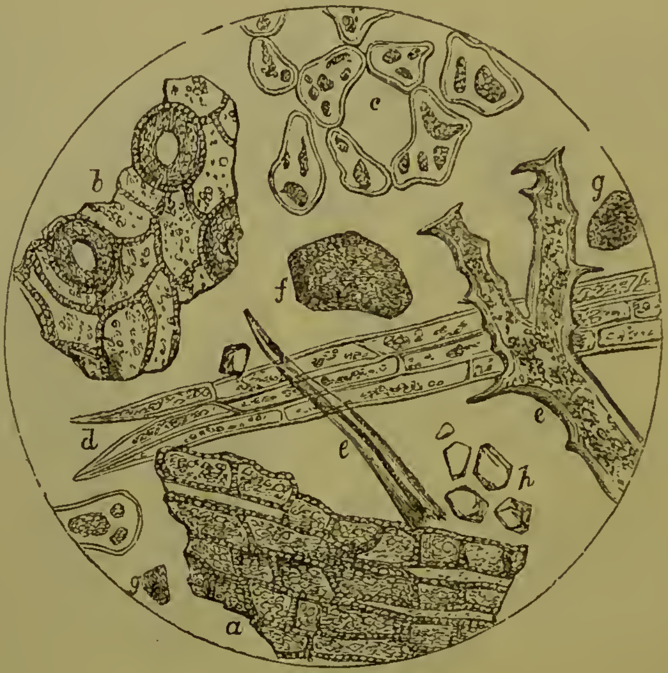


Foreign Leaf in Lie-tea.

a, upper surface of leaf ; *b*, lower surface, showing the cells with their slightly-beaded margins, of which it is composed ; *c*, chlorophylle cells, so disposed as to form very large areolæ ; *d*, elongated cells found on upper surface of the leaf in the course of the veins ; *e*, spiral vessel ; *f*. cell of *turmeric* ; *g*, fragment of *Prussian blue* ; *h*, particles of the white powder, probably *China Clay*.

Among the leaves very frequently employed, in addition to those of the plants already named, are the leaves of *Camellia Sasanqua*, *Chloranthus inconspicuus*, and of *Valonia*. The brick-tea of the Tartars consists of tea-leaves mixed with the leaves and stems of the *Rhamnus Thèezans*, *Rhododendron*, *Chrysanthemum*, *Rosa canina*, and other plants, the leaves being agglutinated with bullock's or sheep's blood. The venation of these leaves, as well as the ultimate structure as revealed by the microscope, differ from that of the tea-plant. The presence of the leaves of Valonia is detected by the acicular crystals observed under the microscope. But other vegetable substances besides foreign leaves are sometimes met with in adulterated teas; in particular *Paddy husk*. Again, some teas often contain an undue proportion of *stalks*.

Fig. 24.

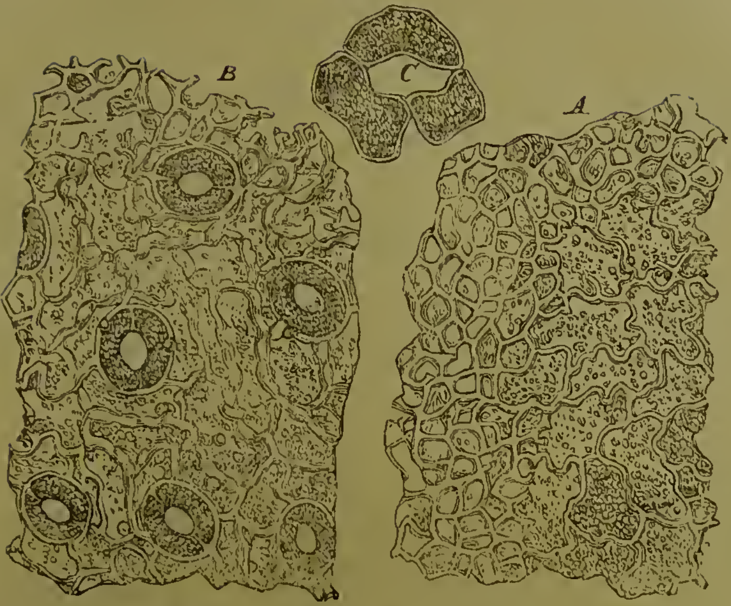


Foreign Leaf in Lie-tea.

a, upper surface of leaf; *b*, lower surface; *c*, chlorophylle cells; *d*, elongated cells; *e*, portion of one of the branched and spinous hairs situated on the under surface of the leaf; *f*, cell of *turmeric*; *g*, fragment of *Prussian blue*; *h*. particles of the *white powder*.

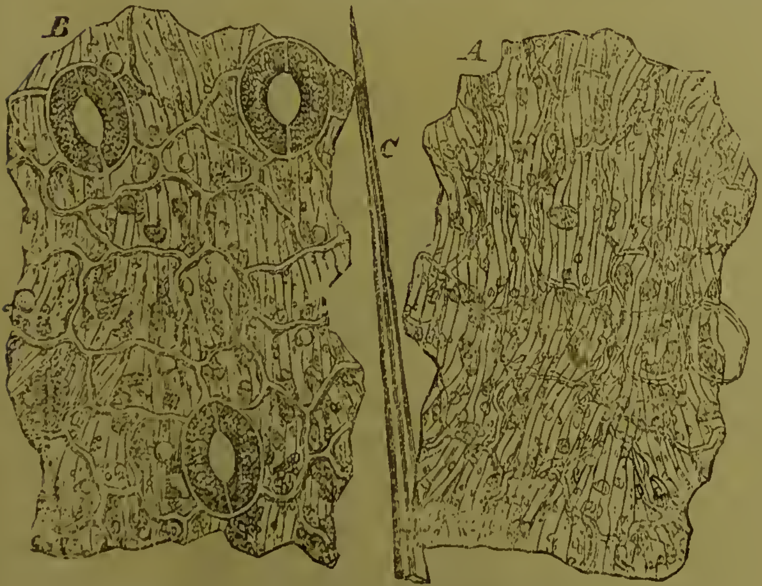
II. *Adulteration with lie-tea.*—We have already adverted to the fact that this article has received the name of 'lie-tea' because it is spurious, and for the most part not tea at all. It consists no doubt in some cases in part of the *dust* of *tea-leaves*, but often of *foreign leaves, sand, quartz*, and *magnetic oxide of iron*—all these being made up with great skill and ingenuity, by means of a solution of *starch*, into little masses of various forms and sizes in imitation of different kinds of tea. These masses, if intended for the adulteration of ordinary black tea, as Congou,

Fig. 25.



Leaf of Camellia Sasanqua, found in Sample of *Twankay.*
A, upper surface of leaf, showing the cells of which it is composed ; *B*, under surface, exhibiting its cells and stomata ; *C*, chlorophylle cells.

Fig. 26.

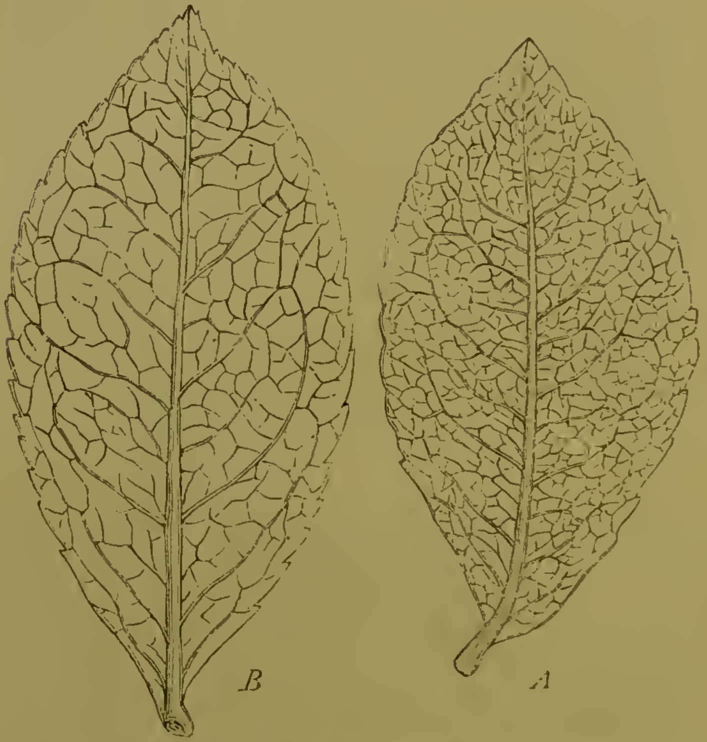


Leaf of Plum, found in sample of *Twankay.*
A, upper surface of leaf ; *B*, under surface ; *C*, chlorophylle cells.

being unfaced, but if designed to imitate caper or Shulan tea, being coated with plumbago or black lead, and if gunpowder, with Prussian blue, turmeric, China clay, or other white mineral powder.

The cleverness exhibited in the manufacture of the different kinds of lie-tea is something really surprising, and so close is the imitation in many cases that much practice and skill are required for its detection. The better descriptions of lie-tea consist of the dust of tea only, made up into little masses, or of this dust mixed with that of foreign leaves; but the great bulk of the lie-tea encountered is compounded of tea-dust, with sometimes the dust of foreign leaves and large quantities of *mineral matter*, of which *silex* and *magnetic oxide of iron* form a considerable proportion, the masses or pellets being artificially coloured or coated with the substances which have been already enumerated. The following analyses, selected from many others, which we have made from time to time, will serve to show the amount of mineral

Fig. 27.



A, leaf of CHLORANTHUS INCONSPICUUS ; *B*, ditto of CAMELLIA SASANQUA ; leaves used to adulterate tea.

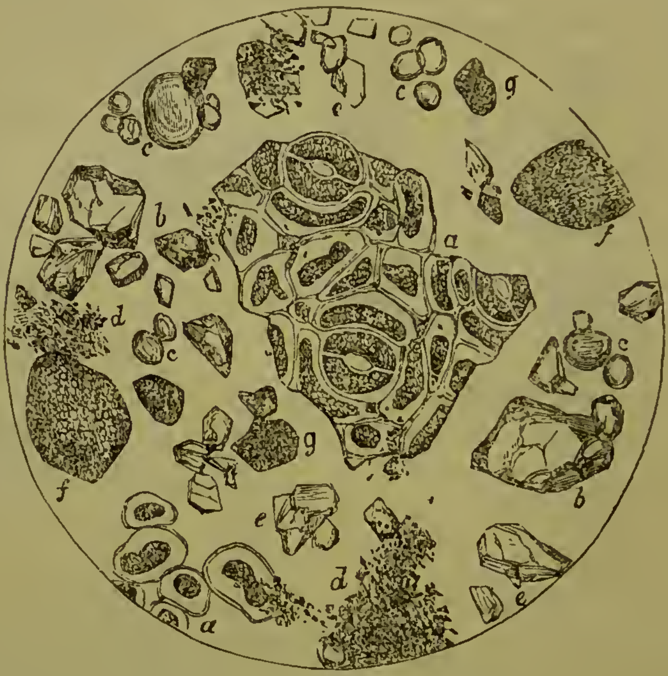
matter contained in this article, as well as the quantities found in a few teas recently examined by us.

Percentage of Mineral Matter in Lie-tea.				Percentage of Lie-tea met with in Tea.			
Black tea.		Green tea.		Black tea.		Green tea.	
Orange Pekoe	28·18	Gunpowder	14·87	Mixed teas	13·0	Mixed teas	23·8
Capers .	31·40	,,	23·82	,, ,,	17·7	,, ,,	12·0
,, . .	25·91	,,	13·13	,, ,,	13·4	,, ,,	9·3
,, . .	33·43	,,	19·76	,, ,,	6·0	Gunpowder	1·38
,, . .	52·92	,,	35·92	Orange Pekoe	7·98	,,	13·68
,, . .	23·34	,,	28·43	The percentages of lie-tea in the capers were not determined.		,,	6·68
,, . .	17·70	,,	24·63			,,	36·67
,, . .	49·76	,,	46·01			,,	37·69
,, . .	13·05	,,	39·97			,,	48·46
,, . .	36·46	,,	30·34			,,	28·95
,, . .	27·20	,,	34·66			,,	39·42
,, . .	26·38	,,	29·30			,,	14·21
,, . .	23·83	,,	32·61			,,	35·23
,, . .	45·70	,,	42·06			,,	20·06
,, . .	15·35	,,	46·62			,,	38·31
,, . .	15·28	Mixed teas	56·34			,,	11·47
,, . .	24·89	,, ,,	19·50			,,	37·30
,, . .	17·61	,, ,,	16·03			,,	26·12
,, . .	23·98					,,	22·98
Mixed teas	26·84						
,, ,,	40·86						
,, ,,	22·11						
,, ,,	20·30						

Mr. Warrington, in a paper read before the Chemical Society of London in 1851, stated: 'On inquiry, I have learned that about 750,000 pounds' weight of these teas have been imported into this country within the last eighteen months, their introduction being quite of modern origin; and I understand that attempts have been made to get them passed through the Customs as manufactured goods, and not as teas—a title which they certainly richly merit, although it must be evident from a moment's consideration that the Revenue would doubtless be defrauded, inasmuch as the consumer would have to buy them as teas from the dealer. It is to be feared, however, that a market for them is to be found elsewhere. The Chinese, it appears, would not sell them except as teas, and have the candour to specify them as *lie-teas*; and if they are mixed with other teas of low quality, the Chinese merchant gives a certificate stating the proportion of lie-tea present with the genuine leaf. This manufacture and mixing are evidently practised to meet the price of the English merchant. In the case of the above samples, the black is called by the Chinese *Lie*

Flower Caper, the green *Lie Gunpowder*. The average value is from eightpence to a shilling per pound. The brokers have adopted the curious terms *gum and dust* as applied to these lie-teas or their mixtures,' a cognomen which at first I had some difficulty in understanding, from the rapid manner in which the first two words were run together.'

Fig. 28.



IMITATION CAPER OR GUNPOWDER.

a a, fragments of the *tea-leaf* or *tea-dust*; *b b*, particles of *sand*; *c c*, *starch corpuscles*; *d d*, groups of granules of *black-lead*; *e e*, particles of *mica-like substance*; *f f*, cells of *turmeric*; *g g*, fragments of *indigo*. Magnified 350 diameters.

III. *Adulteration with mineral matter.*—We have already adverted to the fact that mineral matter, chiefly *sand*, *quartz*, and *magnetic oxide of iron*, enter largely into the composition of lie-tea; but the latter mineral is not unfrequently found in tea independently of lie-tea, while, lastly, *China clay*, *soapstone*, *Prussian blue*, *and other mineral substances*, are extensively employed in the artificial coloration or painting of teas, both black and green. The following table shows the quantities of mineral matter we have met with in adulterated teas, both black and green:—

Quantities of Mineral Matter in Adulterated Teas.

Black tea, chiefly Caper.	
Caper teas	14·94
" "	17·27
" "	18·97
" "	19·32
" "	24·94
" "	14·33
" "	15·33
" "	18·00
" "	8·77
" "	17·89
" "	20·08
" "	15·11
" "	15·48
" "	11·59
" "	8·32
" "	9·84
" "	19·95
" "	11·69
" "	16·61
Siftings	15·32
Mixed teas	12·54
" "	10·51
" "	10·77
" "	9·51

Green tea, chiefly Gunpowder.	
Gunpowder	8·49
"	13·68
"	20·52
"	25·66
"	23·69
"	18·49
"	17·56
"	19·03
"	33·49
"	22·26
"	26·12
"	11·79
"	24·47
"	20·28
"	18·10
"	15·20
"	18·00
"	8·32
Mixed teas	21·83
" "	12·95
" "	13·96

Almost invariably in those cases in which sand and quartz are met with, magnetic oxide of iron is also found. This association is so constant as to render it certain that the mixture either occurs naturally or is specially prepared, and in either case is employed in the adulteration of tea. The following table exhibits the quantities of magnetic oxide of iron actually extracted from various samples of adulterated tea:—

Quantities of Magnetic Oxide of Iron extracted by the Magnet.

Black teas.	
Black tea	0·69
" "	0·36
" "	0·48
" "	1·46
Siftings	8·88

Green teas.	
Gunpowder	1·98
"	5·57
"	2·94
"	8·76
"	1·94
"	2·85
"	1·92
"	3·17
"	1·13
"	1·30
Green tea	0·79
" "	0·10
" "	1·01

A few months back it was a very common thing to read paragraphs in the papers containing the statement that certain teas had been met with which were ascertained on analysis to be adulterated with *iron filings.* In some instances these statements rested on the authority of chemists of high repute. A closer examination of the magnetic particles so frequently found in adulterated teas has revealed the fact that they really consist of the magnetic oxide of iron. Mr. Alfred Bird was, we believe, one of the first to point out this fact, but Mr. P. L. Symonds about the same time affirmed that the article used by the Chinese consisted of titaniferous iron sand. Mr. Bird, however, promulgated the opinion that this iron was derived from the soil, and found its way into the tea from the dust on the leaves. When the large quantity of iron present in many teas, and especially when the proportion of the iron to the sand and other mineral constituents, is taken into consideration, it becomes obvious that this opinion cannot for a moment be sustained.

The principal proofs that the particles in question do not consist of iron filings are the following:—

First, That when examined with the microscope they have not the torn and jagged appearance characteristic of iron filings, but exhibit a crystalline structure, in which the octahedral form is frequently to be discerned.

Second, That they do not reduce the copper from a solution of the sulphate of that metal.

Third, That they dissolve without effervescence, and the evolution of hydrogen in hydrochloric acid.

And, lastly, That they are distinctly polaric—that is to say, the one extremity of them is attracted and the other one repelled by the same pole of the magnet, whereas iron filings are uniformly attracted.

It should be remembered, however, that iron filings when burned become themselves converted on the surface into magnetic oxide of iron.

Iron filings in tea, burnt iron filings, and magnetic oxide are all acted upon by the tannic acid of the tea, tannate of iron being formed, which when burnt yields much ferric as well as some magnetic oxide. The action of the tannin is the most energetic on the iron filings, but its solution produces a dark fluid with the magnetic oxide only. Again, a portion of the magnetic particles may during the incineration of the tea be converted into the ferric oxide.

We will in the next place consider the question whether the presence of this magnetic iron and sand found in the teas here reported upon is attributable to accident merely.

1. We find that magnetic iron is never present in genuine tea—in tea which yields the normal proportion of ash, no matter how low its quality is, and how cheap it may be. We have examined many teas with a view to discover such magnetic particles, and in no instance have we ever met with a single such particle. 2. The cases in which they have been found have all been those in which there has been an

excess of mineral matter, and which has always consisted of silica in the several forms of sand, particles of quartz, and stone. 3. In most of the samples met with the quantity of magnetic iron has been sufficiently great to render the tea itself magnetic, a result which cannot be due to an accidental admixture. 4. That it is not derived from the admixture of soil containing silica and magnetic iron is shown by the fact, that in nearly all cases, after deducting the ash proper to tea, the silica and iron found made up the entire weight of the ash. Now, had these constituents been derived from a soil, there would not have been this correspondence, because a soil, to be fruitful, must consist of many other things besides iron and silica; as alumina, lime, magnesia, soda, potash, phosphoric and sulphuric acids, and chlorine, &c. 5. Again, the quantity of iron found in some of the teas is so considerable, that if calculated into 100 parts of soil, the soil would be found to contain so much iron that it would be worth smelting; this would be the case particularly with those ashes referred to in the above table, which furnish respectively 32, 19, and 24 per cent. of iron, corresponding to 44·6, 26·5, and 33·4 per cent. of magnetic oxide. But, again, the iron found in soils does not exist as magnetic iron, but as ferric oxide and silicate of iron. 6. A great portion of the silica and iron found proceeded from the lie-tea present in nearly all the samples, and into which these substances were, beyond all doubt and question, purposely introduced. We conclude therefore that the iron and silica, quartz and sand, have been specially added. To say that they have made their way into the tea through the dust on the leaves and through carelessness of preparation, is to tax greatly our powers of credulity; besides, as we have already remarked, this view is sufficiently disproved by the large quantities of sand and iron, often 30, 40, and even over 50 per cent. present in the lie-teas, with which nearly all the capers examined were adulterated.

We will again remind the reader that genuine tea yields an ash which rarely, if ever, exceeds 6 per cent.; that the iron in this seldom exceeds ·15 per cent., and is often under that amount; and that the extraneous and accidental silica which we have met with in genuine teas, even in those of the poorest quality and lowest price, seldom exceeds 0·30 per cent. We say accidental silica, having been careful to exclude that natural to the ash of genuine teas.

But, after all, the questions as to whether the extraneous iron found in tea consists of altered, oxidised and burnt iron, or of magnetic oxide; and whether this iron and the silica are derived from dirt, earth or soil, or not, practically matters very little. They ought not to be there; their addition is intentional, as proved by the case of the lie-tea; and they are never present in any really pure teas, no matter how poor their quality and how low their price.

It will be noticed that one of the samples contains no less than 5·86 per cent. of iron. Now, since tea contains a large quantity of tannic acid, we have thus brought together the two chief constituents which enter into the composition of ink; and, by appropriate treatment, a bottleful of ink was manufactured from the tea in question, with which this report was partly written. Now, what has thus been accomplished in the laboratory, it is not improbable may really, in some cases, take place in the human stomach into which ferruginous tea has been received. From these considerations the object of the Chinese in adding iron to tea becomes apparent; the iron is slowly dissolved by the acid of the tea, a tannate of iron is formed, and the colour of the infusion made with such tea thus becomes darkened, and it is to bring about this darkening effect that the iron is in most cases added. The iron would also have the effect of increasing the astringency of the tea, and of rendering it more stimulating. The effect of tannin on bright iron filings is very great, especially if the action be aided by heat. But the same darkening of colour takes place very markedly, though to a less degree, when tannic acid and magnetic oxide of iron are brought together, as in tea. It has been already stated that lie-tea especially furnishes much iron, partly magnetic. Now, since the mineral matter in this so-called tea often amounts to 50 per cent., it is just in such a compound that the iron is especially required, the tea-leaves themselves being so deficient therein.

IV. *The artificial coloration and adulteration of tea.*—A fourth kind of adulteration to which certain descriptions of tea are specially liable consists in the painting or artificial coloration of the leaves. This practice is resorted to for one or more of several purposes. To improve, as some consider, the appearance of some descriptions of tea, especially inferior kinds; for the better concealment of certain adulterations, as where foreign leaves are used, and to disguise more effectually the nature of lie-tea. Several kinds of both black and green tea are liable to be thus artificially coated or coloured. The *black*-coated teas are those known as Scented Caper, or black gunpowder, Orange Pekoe, and the black variety of lie-tea. The substance employed is known by the names graphite, plumbago, or black lead, and is one with which housemaids are particularly familiar. The teas coated with this substance present a particularly smooth and glossy appearance. Graphite contains a small percentage of peroxide of iron, and is non-magnetic.

Occasionally small quantities of the same pigments as are employed in the coloration of green tea are used as well as the black lead, in order to impart a somewhat different hue to the Chulan and black lie-tea.

But it is with *green* tea that the practice of artificial coloration most prevails. The principal green teas imported into this country from China are Twankay, Hyson-Skin, Young Hyson, Hyson, Imperial, and Gunpowder. Now, the colour of nearly the whole of these teas is artificial, and is due to the adherence to the leaves of various colouring matters. Some few years since it was impossible to meet with a Chinese green tea which was not thus artificially coated, but recently samples of uncoloured green have been occasionally brought under our notice. Further, the Indian green teas are almost always free from colouring matter, and the Chinese tea *Oolong*, which, though described as a black, is really a green tea, is equally free from colouring material.

We have already referred to black lie-tea. This is sometimes free from coating, and at other times is coated in imitation of black gunpowder; but very much of it is faced in the same manner as green gunpowder, in imitation of that description of tea.

The usual pigmentary matters employed are *ferrocyanide of iron* or *Prussian blue, turmeric,* and *China clay;* these are mixed in various proportions, so as to produce different shades of blue and green. The leaves are agitated with the mixture usually in a kuo, in which they are subjected to the action of heat, which renders them moist and flaccid, until they become faced or glazed, as it is termed. Occasionally other substances are employed by the Chinese—namely, *indigo, sulphate of lime* or *gypsum, silicate of magnesia* or *soapstone,* &c.

Percentage of Ash in Artificially-Coloured Green Teas.

Gunpowder	7·47
Hyson	6·18
Gunpowder	7·96
Ping Suey gunpowder	6·10
” ” ”	6·49
Moyune gunpowder	6·10
Gunpowder	6·65
”	6·07
Shanghai Ping Suey gunpowder	6·65
Gunpowder	6·68
Ping Suey gunpowder	6·16
” ” ”	6·65
Green tea	6·34
Gunpowder	6·25
Silicote Green tea	6·20
” ” ”	6·07
Young Hyson	6·07
Gunpowder	6·81
”	6·33
”	6·66
”	6·20
”	7·66
Average	6·53

Percentage of Ash, Silica, and Iron in Faced Green Teas.

Name.	Ash.	Silica.	Iron.
Gunpowder	7·47	1·17	0·16
Hyson	6·18	0·84	0·13
Gunpowder	7·96	0·79	0·18
Ping Suey gunpowder . .	6·10	0·53	0·12
" " " . . .	6·49	0·77	0·09
Moyune gunpowder . . .	6·10	0·57	0·11
Gunpowder	6·65	0·73	0·10
"	6·07	0·97	0·11
Shanghai Ping Suey gunpowder.	6·65	0·94	0·12
Gunpowder	6·68	0·74	0·15
Ping Suey gunpowder . .	6·16	0·54	0·09
" " " . . .	6·65	0·75	0·08
Average . .	6·59	0·78	0·12

From the preceding table it appears that the weight of the ash in faced green teas varies from 6·07 the lowest to 7·96, the highest amount; that is, that the mineral facing adds from ½ to 2½ per cent. to the weight of the tea. It is remarkable, notwithstanding the pretty free use in some cases of ferrocyanide of iron or Prussian blue, that the amount of iron in the ash is so little increased; but under the head of 'extraneous silica' we find a sensible augmentation. It is to be noted, however, that the increase in the weight of the ash does not represent the whole of the matter added in the facing, because the Prussian blue is partly destroyed, and the turmeric wholly so, by the incineration. The total addition made may, therefore, be regarded as ranging from one to three per cent., and this of substances which are wholly extraneous to tea, which serve no useful purpose whatever therein, but which help to cover up, conceal, and render possible certain other still more serious adulterations of tea, and which, if not positively hurtful in themselves, yet must be looked upon at least as so much added dust or dirt, helping largely to the consumption of the proverbial peck of dirt.

The practice of colouring teas has prevailed for a very long time, as proved by the evidence of various travellers, testifying to the extent of the practice and the nature of the ingredients used. Dr. Royle writes: 'The Chinese in the neighbourhood of Canton are able to prepare a tea which can be coloured and made up to imitate various qualities of green tea, and large quantities are thus yearly made up.' Mr. Davies states that 'the coarsest black tea-leaves have been cut up, and then coloured with a preparation resembling the hue of green teas,' in imitation of Young Hyson. 'But this was nothing,' continues

Mr. Davies, 'in comparison with the effrontery which the Chinese displayed in carrying on an extensive manufacture of green teas from damaged black leaves at a village or suburb called Honân.' And again he says: 'Certain rumours being afloat concerning the manufacture of green tea from old black leaves, the writer of this became curious to ascertain the truth, and with some difficulty persuaded a Hong merchant to conduct him, accompanied with one of the inspectors, to the place where the operations were carried on. Entering one of these laboratories of fictitious Hyson, the parties were witnesses to a strange scene. The damaged leaves after being dried were transferred to a cast-iron pan, placed over a furnace, and stirred rapidly with the hand, a small quantity of turmeric in powder having been previously introduced. This gives the leaves a yellowish or orange tint; but they were still to be made green; for this purpose some lumps of fine blue were produced, together with a substance in powder, which, from the names given to them by workmen, as well as their appearance, were known at once to be Prussian blue and gypsum. These were titurated finely together with a small pestle in such proportions as reduced the dark colour of the blue to a light shade; and a quantity equal to a teaspoonful of the powder being added to the yellowish leaves, these were stirred as before over the fire until the tea had taken the fine bloom colour of Hyson, with very much the same scent.'

Mr. Bruce states that 'in the last operation of colouring the green teas, a mixture of sulphate of lime and indigo, very freely pulverised and sifted through fine muslin in the proportion of 3 of the former to 1 of the latter, is added; to a pan of tea containing seven pounds about half a teaspoonful of this mixture is put, and rubbed and rolled along with the tea in the pan for about an hour. The above mixture is merely to give it a uniform colour and appearance. The indigo gives it the colour, and the sulphate of lime fixes it.'

Mr. Ball writes: 'So far as the characteristic colour of green tea is concerned, the mode of producing it has been explained and established. If fictitous means are now generally or almost universally adopted to imitate or increase the effect of the natural colour, it may be considered as a great and novel abuse, and ought to be discouraged by brokers and dealers. It is injurious to flavour.'

Mr. Ball quotes the testimony of a respectable Chinese tea merchant and factor, Tien-Hing, to the effect that Twankay tea is often mixed with false leaves, and that it is coloured with indigo, and calcined foliated gypsum. Mr. Fortune, who saw the colouring of tea performed in China, and who has described the process minutely, states that during one part of the operation the hands of the workmen are quite blue. 'I could not help thinking,' he remarks, 'that if any green-tea drinkers had been present during the operation, their taste would have been corrected and improved.'

An English gentleman in Shanghai, being in conversation with some Chinese from the green tea country, asked them, writes Mr.

Fortune, 'What reasons they had for dyeing the tea, and whether it would not be better without undergoing this process? They acknowledged that tea was much better when prepared without having any such ingredients mixed with it, and that they never drank dyed teas themselves; but remarked that, as foreigners seemed to prefer having a mixture of Prussian blue and gypsum with their tea, to make it look uniform and pretty, and as these ingredients were cheap enough, the Chinese had no objection to supply them, especially as such teas always fetched a higher price.'

In the Museum of Economic Botany attached to the Kew Botanical Gardens will be found some specimens of tea dyes procured by Mr. Berthold Seeman from one of the tea factories at Canton. They consist of Prussian blue, turmeric, chalk, and either China clay or gypsum. In the same museum will also be found a series of samples of black and green tea, also of several varieties of lie-tea, all artificially coloured. They were met with by ourselves in the course of our investigations into the subject of the adulterations of tea, and were sent to the museum many years since.

It might be supposed that the practice of thus artificially colouring tea with various mineral and vegetable substances was one which would be universally condemned, and that among analysts, at least, no difference of opinion could exist as to whether it constituted an adulteration or not. This we very greatly regret to state is far from being the case, some analysts boldly excusing the practice, while others say that when the addition is confined to certain limits it is not to be regarded as an adulteration; a view of the matter which is not only wrong in principle, but impossible in practice. Thus, they would say that when the colouring matters do not exceed one or two per cent., such an addition is allowable, but when they exceed that amount the teas so coloured are to fall under the operations of any Act dealing with the question of adulteration. They at the same time overlook the fact that it is impossible with any certainty to determine the exact percentage of colouring matter employed in any particular case, so that no analyst who was careful of his reputation would venture to give evidence for the prosecution in any case of the artificial coloration of tea.

Mr. A. H. Allen, Public Analyst for Sheffield, in answer to a question by the Chairman of the late Adulteration Committee, answers: 'I have stated that I do not call the colouring of green tea an adulteration, and I do not call the colouring in mustard an adulteration.'

Mr. H. C. Bartlett thus expresses his views before the same Committee, with regard to the facing of tea: 'I consider that it would be much better to have tea without any facing, but at the present time the large majority of teas that I have analysed have been faced. Those of the better description have been faced with from 1½ to 2 per cent. of facing material. As those have passed through the Customs and Excise, and have been allowed to be sold in this way, I have not considered in my own mind that there was any great sin on the part of the retailer in selling them, or that he was morally responsible for the sale of these articles merely as tea; *but when it exceeds the amount that has been put in* in that way, although for the purpose of improving the appearance of the tea, then I think the other provision comes in, which brings it distinctly under the clauses of the Adulteration Act—that is, the increasing of the bulk of the article, by the addition of a cheaper or inferior material.' In reply to the question that, if the tea itself was of good quality, and contained from 1½ to 2 per cent. of facing, would he consider it to be adulterated? Mr. Bartlett replied: 'I should much prefer if no facing were allowed; but I should not consider that there is any very great amount of injury to health consequent upon that 1½ or 2 per cent., because of the very fact that Prussian blue in Prussia is entered into the Pharmacopœia as a tonic.' All we can say, as a comment to such a reply as the above, is, may we be delivered from having any of the potent remedies of the Prussian Pharmacopœia poured down our throats under the name of tea!

Again, Mr. Sutton, of Norwich, appears from his evidence to be in favour of allowing a certain amount of facing, but when this limit, which he does not define, is passed, he would call it an adulteration; but in reply to the question of that doughty champion of the tea trade, Sir Henry Peek, 'I think I understood you to say that you would never consider the facing of tea, as it is done in China, an adulteration?' Mr. Sutton answered: 'I do not consider that it should be considered an adulteration under present circumstances, but I do not think myself that the tea need be faced.' Then, in reply to another question, he answers: 'I should not return it as an adulterated article unless it was excessively faced.'

Another witness, Dr. McAdam, replied: 'I would not regard it (the facing) as an adulteration. It is certainly a treatment of the material so as to produce a different appearance from what the tea would naturally present, but it is so well recognised and the quality of the tea is so well known as green tea, that I cannot say that it is an adulteration.'

The following evidence by the same witness is highly instructive, and shows what little help the public have to expect from many professional analysts. A member of the Committee, Mr. C. Garnier, asked the following question: 'In the case of facing tea and colouring cheese and butter, and in colouring whiskey by putting it in sherry casks, and in colouring pickles by copper, and in other cases of colouring, would not the test be whether the colouring was done with a fraudulent intent or not?' To this question Dr. McAdam gave the following answer: 'I think that that certainly should be a test. If it could be proved that sulphate of copper had been added to pickles for the purpose of colouring the pickles, I would say that in any quantity it ought to be called an adulteration; but as the pickles are commonly prepared in a copper pan, the acetic acid or vinegar employed in compounding them will take up a slight trace of copper from the pan, and I do not think that that, if present in pickles, ought to be considered an adulteration.' But, most learned Doctor, the acetic acid will not cease to act on the copper pan when it has taken up 'a slight trace' of copper only, but will continue to act upon the metal as long as the two are in contact. Besides, there is no necessity whatever for the employment of copper vessels in the preparation of pickles.

Dr. C. M. Tidy, who stated to the Committee that he had examined 19,000 samples of articles of food in the course of six years, replied as to the facing of tea, 'I should not like to say very much about it. I am rather disposed myself to think, that it is one of those things which had better not be interfered with.'

Dr. Voelcker said: 'I cannot look upon the facing of tea as an adulteration, because we are so much in the habit of colouring articles of consumption that the dealer has, to a certain extent, to meet the tastes of his customers. I should like to have all articles of food sold without any facing or without any colouring, but then this colouring is a delicate question, because if you allow it in one article of food, it strikes me that you ought not to interdict it in another article of food, and if you were to set your face entirely against all colouring, it would be difficult to say where to stop.' The same arguments might and indeed have been employed over and over again in justification of nearly every species of adulteration practised. Nothing is more common than to hear many adulterations justified on the plea that they are perpetrated to meet the tastes of customers. Again, if objectionable practices are to be upheld simply because of their prevalence, then since adulteration itself in all its many forms is extensively practised, it is well, according to Dr. Voelcker's line of reasoning, not to interfere with it at all.

After the above evidence, it is not a little amusing, as well as somewhat surprising, to come upon the following admission. After making the extraordinary statement that an analytical chemist can do very little in the examination of tea, and that a man who has got practical experience is a far more reliable judge of the purity of tea, Dr. Voelcker remarks: 'I may say, whilst on the subject of tea, that I have never found any adulterated tea.' An admission which surely deprives the evidence of the Doctor of any value which it might otherwise have possessed. We may say for ourselves that at least 100 samples of adulterated tea have passed through our hands in the last few months.

The last witness whose evidence we shall quote is Mr. Wanklyn. When asked 'Do you regard the facing of tea as an adulteration?' he replied, 'No; I regard it as a perfectly legitimate practice.' And again, 'Then you contradict the last witness (Dr. Hassall) very flatly upon that point?' 'Quite flatly.' 'But you agree with almost all the other scientific witnesses we have had, who have almost all said that the facing of tea is not an adulteration?' 'I agree with them perfectly, and for the reason that facing is not necessarily injurious to health, and that faced tea does not add sensibly to the weight or volume of the tea. It adds to the weight or volume just in the sense that, to throw a bucket of water into the Thames would increase the river; but it does not add to the volume in any sensible manner.'

Is it possible to conceive of any scientific witness giving more absurd evidence than this? The colouring matters employed in the facing of tea amount to from 1 to 3 per cent., and they do therefore add sensibly to the weight of tea; and Mr. Wanklyn's comparison of throwing a bucket of water into the Thames is simply ridiculous; but as we have so often remarked before, the objections to the coloration of tea are not confined to the quantity or the character of the substances employed, and the practice is to be emphatically condemned in every degree, whether it be carried on to a small or large extent, on the ground that it is resorted to, in many cases, to cover and conceal other more injurious and fraudulent adulterations.

RESULTS OF THE RECENT EXAMINATION OF CAPER, GUNPOWDER, AND OTHER TEAS.

Adulterated Caper.—Of Chinese teas some descriptions are more liable to adulteration than others, the capers and gunpowders being specially so.

1. Thus of twenty samples of *Caper Tea*, fully reported upon in 'Food, Water, and Air,' for November 1873, one only was genuine, the Foo-Chow caper, and nineteen were adulterated.

2. All the nineteen contained lie-tea; were faced with plumbago, contained iron, chiefly in the state of magnetic oxide, sand, and quartz in variable quantities.

3. The quantity of iron in excess of that normally present in the ash of genuine tea varied from 0·06, the smallest amount met with, to 5·86 per cent., the highest quantity found, the iron being present in many cases, both in the caper and in the lie-tea, especially in the latter.

4. The quantity of sand and stony particles in the whole tea varied from 2·09 to 12·83 per cent., and the amount of ash in the lie-tea from 13·05 to 52·92.

5. Eight of the teas contained foreign leaves, which were present in some of the samples in considerable quantities.

6. The extractive matter of genuine green tea, of which caper for the most part really consists, amounts to nearly 40 per cent., whereas the quantity in the adulterated teas varied from 26·69 to 37·94 per cent.

7. The quantity of theine, which in genuine green tea amounts to about 2·3 per cent., ranged in the adulterated teas from 0·82 to 2·68 per cent., if we except one sample, in which the quantity of theine was unusually high.

Some further details of the analyses of the samples above noticed are given in the subjoined table:—

Table of Adulterated Caper Teas.

Ash of whole tea.	Ash of Lic-tea.	Iron (extraneous).	Silica (extraneous).
14·94	31·40	0·59	8·35
17·27	much	0·06	11·21
18·97	25·91	0·67	11·64
19·32	33·43	1·48	11·45
24·94	52·92	5·86	12·83
14·33	23·34	0·44	7·69
15·33	17·70	1·10	8·20
18·00	49·76	0·26	12·00
8·87	13·03	0·29	2·86
17·89	36·46	2·09	9·30
20·08	27·20	1·38	11·13
15·11	26·38	2·24	7·25
15·48	23·86	0·79	8·72
11·59	45·70	0·56	4·86
8·32	15·35	0·23	2·27
9·84	15·28	0·21	3·48
19·95	24·87	2·04	10·76
11·69	17·61	0·16	6·09
16·61	23·98	1·10	9·28

Adulterated Gunpowder.—1. Of eighteen samples of *Green Tea* analysed and reported upon in 'Food, Water and Air,' for January 1874, seventeen being samples of gunpowder tea, and one of Hyson tea, *the whole were adulterated.*

2. *The whole of the teas were artificially coloured* or faced, in sixteen cases with Prussian blue, turmeric, and a white mineral substance, usually a silicate, and in the two other samples with Prussian blue and the white powder only.

3. Sixteen of the samples contained *lie-tea*, which, with one exception, ranged from 6·68 to 48·46 per cent. of the tea.

4. The quantity of *iron* in the teas, excluding four samples, ranged from 0·47 to 4·47 per cent.

5. The iron existed in all cases as *magnetic oxide of iron*, and in no instance were 'iron filings' found. This result has been confirmed by the examination of a great number of other teas, and it now, therefore, appears that, notwithstanding all the statements made and promulgated as to the frequent presence of iron filings in tea, they are of rare occurrence, even if they are ever found there.

6. The quantities of *magnetic oxide of iron* actually extracted from several of the teas were as follow:—1·98, 5·57, 2·94, 8·76, 1·94, 2·85, 1·92, 3·17, 1·13, and 1·30 per cent.

7. The quantities of *silica, sand,* and *stony particles* found in

the whole tea, excluding the two teas which were faced only, varied from 2·52 to 19·19 per cent., and the ash of the lie-tea from 13·13 to 46·01 per cent.

Further results of the above analyses are shown in the following table:—

Table of Adulterated Gunpowder Teas.

Percentage of Lie-tea.	Ash of whole tea.	Ash of Lie-tea.	Iron.	Silica.
*1·38	8·49	14·87	0·12	2·52
13·68	18·00	23·82	0·36	10·90
6·68	8·32	13·13	0·15	2·95
36·67	20·12	19·76	1·35	12·14
37·69	25·66	35·92	3·01	15·86
48·46	23·69	28·43	1·79	14·46
28·95	18·49	24·63	0·51	10·32
39·42	17·56	20·33	0·47	9·02
14·21	19·03	46·01	0·18	12·31
35·23	33·49	39·97	4·47	19·19
20·06	22·26	30·34	1·43	13·02
38·31	26·12	34·66	2·33	16·20
11·47	11·79	29·30	1·18	4·12
37·30	24·47	32·61	2·48	14·85
26·12	20·28	42·06	0·94	13·17
22·98	18·19	44·62	0·82	11·80

Of the above teas, the whole, except the one thus distinguished (*), were decidedly, and many of them, very strongly magnetic.

From the analyses above given it is therefore evident that the practice of adulterating tea widely prevails, and is of a very shameful character. As was the case with the Caper teas, most of the green teas now examined came from Canton, which place is the great centre and focus of the adulteration of tea; this fact is perfectly well known to all who have anything to do with tea—merchants, brokers, wholesale and retail dealers, and who therefore have no just right to urge the plea of ignorance in extenuation. The merchant who wants genuine tea would scarcely go to Canton for it; and if he did go there at all, this very circumstance would alone tend to prove that what he actually required was something very different from genuine tea. Besides, the British merchant's interests in China are protected, we believe, in all cases, by the presence at the several places of manufacture and export, of carefully trained experts, on whom it would be impossible to impose; so that when such rubbish as were many of the samples here reported upon are purchased by English houses, they know well what they are buying, not only from the samples themselves, but from the prices which they pay for such so-called tea.

The statement has been frequently made from time to time that green tea often contains *copper*, is coloured, in fact, sometimes by that metal, which is assumed to be derived from the copper vessels used in drying the tea. This assertion we have put to the proof by testing the ashes of the foregoing teas, and with the result of not finding even a trace of copper.

Another statement made, is that *sulphate of iron* is often added to tea by the Chinese to increase the astringency of tea, to darken the solution, and to render the beverage more stimulating. The strongly ferruginous character of some of the ashes led me to suspect that possibly extraneous iron was present in some of the samples in that form as well as in the state of magnetic oxide; the several ashes were therefore-tested for sulphuric acid, 0·50 per cent. only being found in 100 parts of the mixed ashes of the lie-teas, this being much less than the quantity often present in genuine tea; thus Liebig found 8·72 per cent. of sulphuric acid in the ash of the watery extract of tea.

So far, then, as these analyses go, this statement also is not corroborated.

Lastly, a portion of the lie-tea of several of the foregoing samples was separated, reduced to powder, the ash and extract estimated; the ash amounted to 24·07 per cent., thus leaving, after making the allowance of 6 per cent. for the normal ash, 82 per cent. of what we will presume to have been tea. This should furnish, taking 40 per cent. as the full extract obtained from genuine tea, 32·8 per cent. of extract. But the actual amount obtained from the lie-tea was no less than 47·3 per cent.—that is to say, the largely adulterated lie-tea furnished an amount of extract much exceeding that obtained from genuine tea, proving plainly the presence of some foreign soluble matter.

Relative to this point the author has also made some examinations. He re-examined the samples of green tea adulterated with lie-tea, the results of the analyses of which have just been referred to, and he found that in all cases the adhesive material, wherewith the tea, sand, and magnetic oxide of iron, &c., entering into the composition of the lie-tea, were incorporated into little hard masses, consisted of *boiled starch* in large quantity; indeed in amount sufficient to account in great measure for the high percentage of extractive usually furnished by teas adulterated with lie-tea. The detection of the starch by means of a solution of iodine was, of course, very readily effected.

The eighteen samples of green tea already noticed were also examined for *foreign leaves*, which were found to be present in five of the samples; but the leaf-dust entering into the composition of the 'lie-tea' was not examined, and it is in this that the presence of broken-up leaves, not tea, might be looked for.

Other kinds of tea which are also very liable to adulteration are Scented *Orange Pekoe* and sometimes *tea-siftings*. The results of the analysis of one sample of Orange Pekoe were as follows:—Magnetic, faced with plumbago, or black lead, and containing 7·98 per cent. of lie-tea. Ash of the whole tea, 10·48 per cent., containing 0·29 per cent. of iron and 4·26 per cent. of sand. Ash of lie-tea, 28·18 per cent. This tea, therefore, was adulterated with plumbago, lie-tea, sand, and magnetic oxide of iron.

The analysis of a sample of *siftings* furnished the following results:—It formed a black powder, highly magnetic, clinging to and covering the magnet in long threads. Ash, 15·20 per cent., containing 3·96 per cent. of iron, and 6·24 per cent. of sand and stony particles. Extracted by means of the magnet, 8·88 per cent. of magnetic oxide of iron.

This tea, then, was also much adulterated with magnetic oxide of iron and silica, the tea from which the dust was derived being no doubt similarly adulterated. However, here the author would wish to say a few words on behalf of tea-dust in general. He has examined many samples of it, and found it to be genuine in nearly all cases. This article is not known to the public at large, and is much used for mixing. It is sold at a very low price, and when genuine it would be a real boon to the poor, if obtainable by them.

The quantities of extractive matter and of theine yielded by adulterated teas is as a rule of course less than those obtained from genuine samples; but the data thus furnished are not sufficiently marked to afford absolute proof of adulteration. We here append a table, showing the amount of extractive matters and of theine obtained from adulterated capers and other teas.

Percentage of Extractive Matter and of Theine in Adulterated Teas.

Caper	26·69	0·97
”	28·29	1·66
”	30·99	1·63
”	32·39	1·14
”	30·67	1·29
”	28·49	1·54
”	31·79	0·95
”	32·94	1·28
”	37·94	2·26
”	34·39	1·06
”	32·31	1·76
”	34·48	2·23
”	32·06	2·05
”	32·37	2·68
”	30·06	1·94
”	36·02	3·30
”	31·18	0·82
”	38·69	1·85
”	38·04	1·59
Mixed Black	30·27	1·50
” ”	29·39	2·13
” ”	28·59	1·09
Mixed Green	34·48	0·92
” ”	32·58	0·93
” ”	35·90	1·11
Average	30·04	1·58

The quantities of extractive matter, as shown in the above table, are certainly higher than might have been anticipated, considering the extent to which many of the teas were adulterated, the average being 32·04. This arises doubtless, partly from the fact that the Caper teas, from which most of the extracts were obtained, partake rather of the nature of green than of black tea, and partly from the starch present in the lie-tea.

The following table gives the results of the analysis by the author of the teas which formed the subject of recent prosecutions in Birmingham, and in most of which convictions were obtained:—

No.	Action on magnet.	Facing.	Lie-tea.	Ash of Lie-tea.	Ash of whole tea.	Iron.	Silica.*	Magnetic iron extracted.	Total organic extract.	Theine.
1	Attracts the magnet.	Turmeric & Prussian blue . . .	23·8	56·34	21·83	0·51	14·68	0·79	34·40	0·92
2	Slightly magnetic.	Plumbago . .	13·0	26·84	10·51	0·83	4·15	0·69	29·39	2·13
3	Ditto . .	Turmeric, Prussian blue, and a white powder . .	12·0	19·50	12·95	0·74	4·66	0·10†	32·58	0·93
4	Ditto . .	Plumbago . .	17·7	40·86	9·51	0·58	3·08	0·36†	28·59	1·09
5	Decidedly magnetic.	Turmeric, Prussian blue, and a white powder . .	9·3	16·03	13·96	0·56	5·91	1·01	35·90	1·11
6	Magnetic .	Plumbago . .	13·4	22·11	10·77	0·51	4·32	0·48	31·07	—
7	Strongly magnetic	Plumbago . .	6·0	20·30	12·54	0·83	4·70	1·46	30·27	1·50

* Insoluble in *aqua regia*.

† In these cases the lie-tea had been previously partly removed, and with it much of the magnetic iron.

THE ADULTERATION OF TEA AS PRACTISED IN THIS COUNTRY.

Many years since a very high duty was levied upon tea, and this led to its being very extensively adulterated in this country. Since, however, the reduction of the duty, which is now only sixpence in the pound, but little sophistication takes place. The practices resorted to were various, and on the whole much more objectionable and dangerous than those of the Chinese.

One common proceeding was to collect exhausted tea-leaves, to mix them with a solution of gum, catechu, and sulphate of iron, and to re-dry them. The gum supplied in a measure the place of the extractive matter removed from the leaves by their previous use, and the catechu and the sulphate of iron gave the solution astringency and colour.

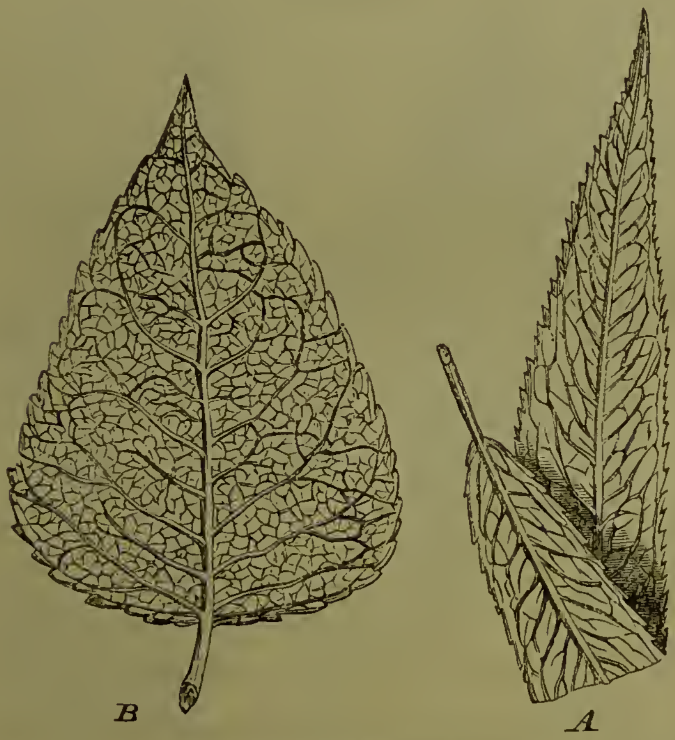
Another practice was, to collect the leaves of different plants, to break them up, to mix them with catechu, and to granulate the mixture in imitation of the lie-tea of the Chinese, which has already been described.

These masses were finally coated, either black or green, in imitation of black or green gunpowder teas, with a variety of pigmentary substances, some of them of a highly poisonous nature.

In former years many seizures were made by the Excise authorities, for the sale of teas, adulterated in this country in one or other of the ways above described.

Among the *leaves* which have been known to be thus employed are those of the *sloe, beech, box, elm, horse-chestnut, plane, bastard plane, fancy oak, willow, poplar, hawthorn*, and *sycamore*.

Fig. 29.



A, Leaf of Willow; *B*, ditto of Poplar.

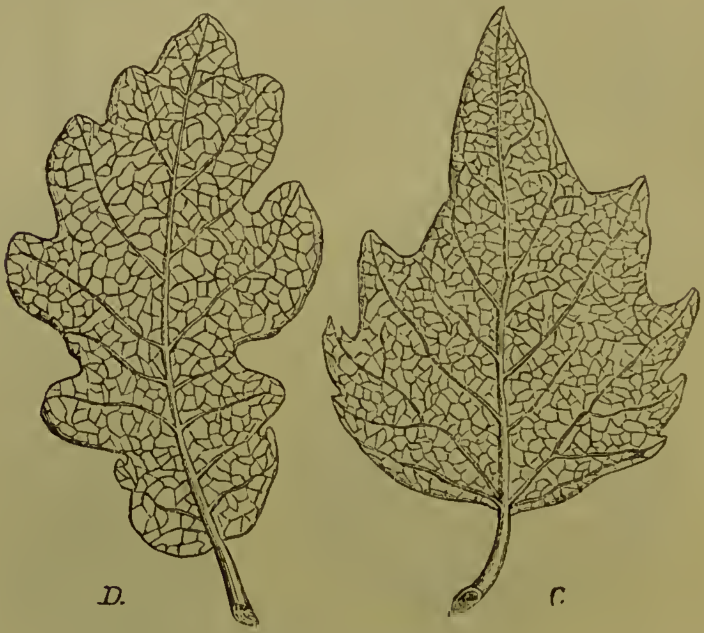
The colouring matters employed and actually detected were *rose pink, Dutch pink, catechu, chromate of lead, sulphate of iron, Venetian red, carbonate of copper, arsenite of copper, the chromates of potash, Prussian blue, indigo, carbonate of lime, carbonate of magnesia* and *silicate of magnesia* or *soapstone*, also called *French chalk*.

Carbonate of copper occurred to the extent of 35 per cent. in some tea which was seized in London by the Excise in 1843.

The tea into the facing of which the chromate of potash entered was seized in Manchester in 1845. At the same time the following articles were found on the premises, evidently intended to be used in the colouring of adulterated tea:—A mixture of chromate of lead, carbonate of lime, and arsenite of copper; a mixture of indigo, chromate of lead and carbonate of lime; a mixture of arsenite of copper, carbonate of magnesia and Venetian red.

In 1848 other seizures of green tea occurred. In some instances the colouring matters employed amounted to 7, 8, and even 9 per cent. of the teas.

Fig. 30.



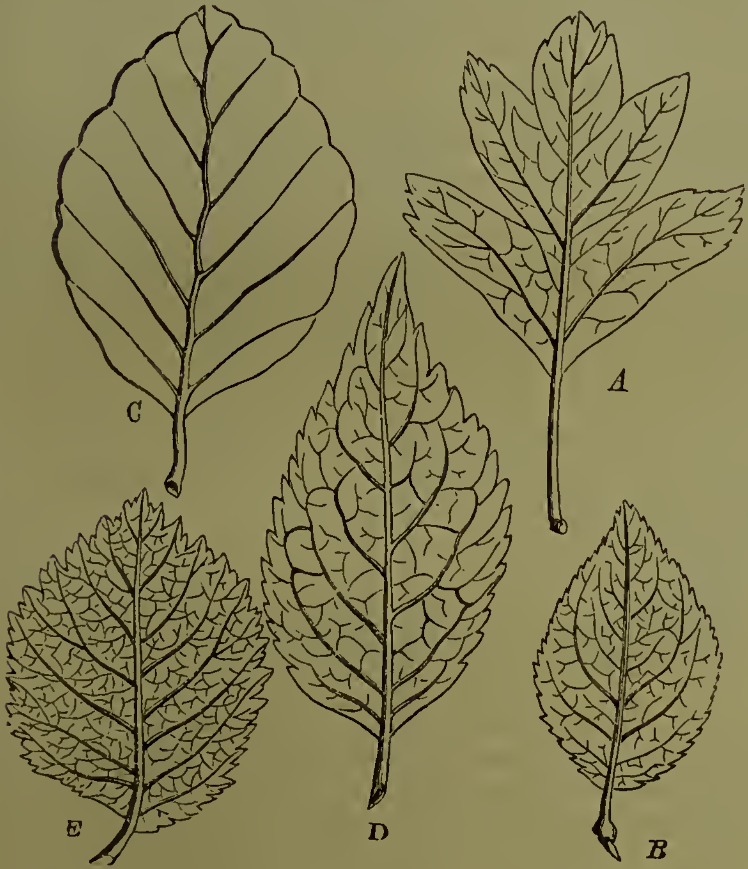
C, Leaf of PLANE; *D*, ditto of OAK.

Of course, the teas fabricated in the ways above described were not sold alone, but were used for mixing with genuine teas.

Mr. George Phillips, of the Inland Revenue Office, states, in reference to the employment of exhausted tea-leaves, that in 1843 it was supposed that there were eight manufactories for the purpose of re-drying exhausted tea-leaves in London alone, and several besides in various parts of the country. Persons were employed to buy up the exhausted leaves at hotels, coffee-houses and other places, at twopence-halfpenny and threepence a pound. These were taken to the manufactories, rinsed with a solution of gum and re-dried. After this the dried leaves, if for black tea, were mixed with rose pink and black lead to face them, as it is termed by the trade.

A case illustrating the manufacture of spurious tea in this country occurred in Liverpool, in December 1850, where a regular manufactory was discovered, carried on by a Mr. John Stevens. Samples of the article then seized were presented to us by the late Dr. Muspratt and Mr. Phillips. One of the samples consisted of a mixture of the entire dried leaves of the sycamore and horse-chestnut. In another specimen the leaves were so broken down

Fig. 31.



A, Leaf of the Hawthorn; *B*, ditto of the Sloe, or Wild Plum; *C*, ditto of the Beech; *D*, ditto of the Elder; *E*, ditto of the Elm.

⁂ The whole of the leaves, except that of the camellia, are figured on their under surfaces. The elm, plane, and oak leaves, from which the sketches were prepared, were of small size.

that it was scarcely possible to identify them without the aid of the microscope. A third sample consisted of large lumps of irregular size and shape, formed of the broken leaves, including even the stalks, agglutinated by means of catechu. In another specimen these masses were broken down into smaller masses or fragments, resembling those of gunpowder tea. In this state the article was ready either for mixing with genuine black tea, or for being faced in imitation of green gunpowder. Lastly, other samples were coloured with indigo, and then they very closely resembled the green gunpowder tea of the Chinese.

In 1851 a manufactory of spurious tea was discovered at 27½ Clerkenwell Close, Clerkenwell Green. Inspector Brennan deposed that he found the prisoners in an apartment busily engaged in the manufacture of spurious tea; there was a furnace before which was suspended an iron pan, containing sloe-leaves and exhausted tea-leaves. On searching the premises an immense quantity of used tea and bay-leaves was discovered, some of which were mixed with a solution of gum and sulphate of iron. In a back room about 100 pounds of re-dried tea-leaves, bay-leaves and sloe-leaves were found spread on the floor drying.

THE DETECTION OF THE ADULTERATIONS OF TEA.

The detection of the adulterations of tea may be considered under the five following heads:—

1. Foreign leaves.
2. Exhausted tea-leaves.
3. Lie-tea.
4. Quartz, sand and magnetic oxide of iron.
5. Colouring substances employed for painting or facing the teas.

I. *Detection of foreign leaves.*—The leaves may occur in two states, either more or less entire or broken up into fragments, which may be found either loose in the dust of tea or else agglutinated by means of a solution of starch into masses, forming lie-tea, and which may be either uncoloured or artificially coloured black or green.

For the detection of the foreign leaves a thorough acquaintance with the tea-leaf itself is necessary; its shape and various sizes, the crenation of the edges, its venation, and, lastly, its structure as shown by the microscope, embracing particularly the size and form of the cells and stomata and the form and the distribution of the hairs. All these points are well delineated in the figures of the tea-leaf already given.

A knowledge of the characters of the leaves most likely to be encountered in adulterated tea is also very desirable, and will facilitate their identification. To discover foreign leaves in a more or less entire state, the tea should be infused in boiling water for a few minutes and all suspicious pieces spread out, and the characters visible with the naked eye compared with those of the tea-leaf. Furthermore, portions of any suspected leaves should be examined with the microscope on both the upper and under surface. For the detection of foreign leaves when reduced to the state of dust the microscope must be resorted to, and if lie-tea is examined, the masses of which it is composed are to be disintegrated by means of hot water, and the fragments of leaf thus liberated diligently and carefully examined with that instrument.

In searching for foreign leaves it will occasionally happen that other extraneous vegetable substances are met with, especially *paddy husk* or the *husk of rice.*

II. *Detection of exhausted tea-leaves.*—Exhausted tea-leaves are rarely used without being subjected to a special process of preparation. Of course they are re-dried, but in addition they are generally mixed with a solution of gum, to restore something of the appearance natural to them in their unused condition. But when thus re-dried and treated, it is not difficult to discover by the eye alone that they have been used before. Thus, the fold or roll of the leaves is less regular and uniform than that of unused tea, and many flat pieces of leaves occur, the surfaces being often agglutinated together.

Again, the gummed leaves present an unnaturally glossy appearance.

In doubtful cases, however, a chemical analysis will be required—that is to say, the percentage of extractive matter, with the proportion of tannin and especially of gum, must be determined. The weight of the ash, and particularly that portion of it soluble in water, will also afford useful data. In unused tea the proportion of extractive matter is on an average in black tea 33·85 and in green 41·20 per cent. The amounts of tannin and gum will of course vary with the extractive matter, but a black tea furnishing 33·25 extractive matter will be found to yield about 15·2 tannin and 5·7 gum. In adulterated teas, however, all these constituents are of course greatly reduced, and in some cases even amount only to a very few percentages.

For the composition of genuine and unused black and green teas the reader is referred to the analyses, already given, and we now subjoin original analyses of two teas not absolutely exhausted, but of leaves taken without selection from the teapots of two different families:—

I.

Used tea-leaves, from a family teapot:—

Total extractive matter . .	7·20	containing
Gum	4·66	
Tannin	trace	
Theine	1·06	
Soluble ash of leaves . . .	1·86	
Insoluble ash of leaves . .	2·91	
Nitrogen of leaves	3·10% = 17·85 of albuminous matter, *minus* the nitrogen of theine.	

II.

2 teaspoonfuls of tea, 1½ breakfast cup of infusion:—

Total extractive matter	15·15	containing
Theine	1·20	
Tannin	2·65	
Gum	8·39	
Soluble ash of leaves	1·88	
Insoluble ash of leaves	2·42	
Nitrogen of leaves	3·36% = 19·32	of albuminous matter, *minus* the nitrogen of theine.

But exhausted and re-dried leaves have been in former years occasionally found to be mixed with sulphate of iron. They are also sometimes faced in imitation of green tea. The sulphate of iron would, of course, be present in any solution made from the leaves, and both the sulphuric acid and the iron might be estimated in the ash. For the estimation of these see pp. 85 and 111, and for the detection of the facing the reader is referred to Section V., p. 141.

III. *On the detection of lie-tea.*—The detection of lie-tea is by no means difficult. Formerly samples were commonly to be met with consisting wholly of lie-tea made up in imitation of a variety of other teas, black and green, especially gunpowder; but now it is found only intermixed with other teas, especially with those above referred to. For its detection a portion of the tea should be spread out on a sheet of paper and examined with a lens, and all suspicious particles removed. The little masses of lie-tea consist of tea-dust, and sometimes other substances, agglutinated together with a solution of starch; the masses so formed usually present a very different appearance to the eye in texture, form, and weight to portions of the tea-leaf itself, and by these characters they may be readily distinguished by a person once accustomed to their appearance without any further examination. But should there be a doubt, this is at once solved by pouring upon the masses a little boiling water, when, if they consist of leaves, they will quickly unfold and expand, whereas, if of lie-tea, they will break down and become disintegrated, leaving a dirty residue, in which minute particles of the tea-leaf are visible.

But lie-tea is usually admixed with quartz or sand, and very often with magnetic oxide of iron. If any of these substances be present, and one of the little masses be placed between the teeth, it will feel gritty; and if the finger be pressed upon them when rendered soft by the action of hot water, the sand or other mineral matter will be at once felt.

For the separation and estimation of the above three substances processes have already been given (see p. 111), while for the detection and determination of the facing the reader is referred to Section V.

The weight of the ash of lie-tea, after deducting the normal percentage of ash of tea, namely, 6 per cent., gives roughly the amount of the mineral adulterants contained in the lie-tea.

IV. *Detection of quartz, sand and magnetic oxide of iron.*—A process for the estimation of the first two of these has already been given under the head of 'Analysis of the Ash,' and is the same as that for silica, as also a process for the determination of the iron. But the magnet forms a very valuable means whereby not only the presence of magnetic oxide of iron in tea may be determined, but its amount ascertained with considerable accuracy. For this purpose a weighed quantity of tea must be pulverised in a mortar, and little by little the whole of the magnetic oxide removed by a magnet. This object is thus effected. A few grains of the powder are spread on a sheet of white paper, the magnet being drawn along its under surface so long as any particles are attracted, and which should be brought to the edge of the paper. The magnetic oxide thus obtained is more or less intermixed with the dust of the leaves, which is got rid of by gentle incineration or by the action of a solution of caustic potash. A quicker, and perhaps a more complete, method of separation is to plunge the magnet into the powdered tea so long as any particles adhere to it, and then to subject them to incineration.

Another and still readier method is to separate the particles of magnetic oxide of iron from the ash of the tea, it undergoing but little oxidation unless subjected to a very strong and prolonged heat.

V. *On the detection of the facing of tea.*—As has been already stated, a variety of substances are employed in the facing of tea. Of these the principal are graphite or black lead, the material with which pencils are made and fire-grates and fenders polished, Prussian blue, indigo, turmeric, and certain white mineral substances, especially China clay or Kaolin, which is a silicate of alumina; but occasionally soapstone or silicate of magnesia and gypsum or sulphate of lime are employed.

Not unfrequently shining particles of mica may be observed on the surface of faced teas. These are usually derived from the China clay, which itself consists of disintegrated and decomposed granite.

The mixture of a blue, yellow, and white pigment in different proportions gives rise to various shades of green, from blue green to bright and even yellow green.

The detection of all the substances above referred to is by no means difficult, but the first thing to determine is whether the tea is artificially coloured or not. For this purpose several different methods may be pursued. A few of the leaves may be viewed as opaque objects under the microscope with a glass of one-inch focus, when the colouring matters entering into the composition of the facing will be detected as minute specks or particles dotting the surface of the leaves, and each reflecting its appropriate tint.

Another method is to place a small quantity of the tea in a piece of muslin and to shake it well over a sheet of white paper, to collect the dust which passes through, and to examine it under the microscope in the same manner.

Or the dust found in most packages of tea may be taken and similarly examined.

Or, lastly, a portion of tea may be washed with cold water, the washings being set aside for a time, when the pigmentary substances thus removed from the surface of the leaves will gradually subside to the bottom of the glass. By the latter proceeding, carefully carried out, an estimation of the quantity of the materials employed in the facing may be made.

Having by one or the other of the above methods determined whether the samples be faced or not, the next step is to ascertain the nature of the substances used.

Ferrocyanide of iron or Prussian blue.—The blue colouring matter employed by the Chinese almost always consists of Prussian blue or indigo, but generally the former. The Prussian blue may be recognised under the microscope by the angular form of the fragments, their brilliant and transparent blue colour, and by the action of a drop of liquor potassæ, which quickly destroys the blue, turning the fragments of a dull reddish tint, the original colour being restored on the addition of dilute sulphuric acid. The re-agents may be readily applied in very minute quantities to the smallest fragments of Prussian blue visible in the field of the microscope; the caustic potash decomposes the ferrocyanide of iron, forming ferrocyanide of potash and oxide of iron. On the addition of the acid, sulphate of potash is formed, and the hydroferrocyanic acid again unites with the iron, the oxygen of the iron uniting with the hydrogen of the latter acid to form an atom of water.

If a quantitative determination of the ferrocyanide of iron present be required, an ounce or two of the tea should be washed in water to remove the facing; the washing should be set aside until this has subsided, it should then be collected, burnt, and the ash treated in the manner already described (p. 111), under 'Iron.'

On the detection of indigo.—This substance is distinguished under the microscope by the granular texture and greenish-blue tint of the particles, but chiefly by the fact that the colour is not discharged by liquor potassæ at ordinary temperatures. For the purpose of obtaining it in any considerable amount two or three ounces of the tea must be washed, and the same proceeding adopted for separating it as in the case of Prussian blue. If obtained free from any large admixture with tea-dust, it may be chemically identified by its furnishing a deep blue solution with fuming sulphuric acid, which solution, after dilution with water, is bleached by chlorine and permanganate of potash; or by placing the dried powder in a test-tube and subjecting it to the action of heat, when the indigo will sublime as a violet vapour, which will condense in the cool part of the tube, forming beautiful needles.

But the best method of identifying indigo is based upon the fact, that it yields, on heating with caustic potash, aniline, which may readily be detected by its striking a beautiful magenta colour with hypochoride of lime or bleaching powder. For the success of this test it is necessary that the indigo should be but little contaminated with organic matter.

A method of quantitative estimation might be founded upon its property of being destroyed and decolorised by a solution of permanganate of potash. For this purpose a solution of indigo and sulphuric acid of known strength should be made; it should be determined by experiment how much of a solution of permanganate would be required for its discoloration. The indigo obtained from a weighed quantity of tea is then dissolved by means of sulphuric acid, and the amount of permanganate solution necessary to its complete discoloration is likewise estimated. Thus all the data would be obtained which are necessary for the calculation of the amount of indigo present in the tea.

On the detection of turmeric.—The microscope is the only means of identifying turmeric. It consists of characteristic yellow cells, of a rounded form, which are filled with starch granules of a peculiar shape. The cells on the addition of an alkali turn brown, swell up, and the outlines of the large starch granules become visible (see 'Turmeric').

On the detection of black lead.—The jet black glossy and metallic lustre imparted to substances coated with this material is so characteristic as to serve in most cases for its identification. Apart from the evidence afforded by the eye alone, it may be detected in other ways. If a thin slice be removed from the surface of one of the leaves faced with this substance, and placed under the microscope, it will be seen to be thickly studded with numerous black particles.

Again, if one or two teaspoonfuls of black-leaded tea be infused in boiling water, the liquid will in many cases, where the quantity of facing is considerable, acquire a blackish hue, and on evaporation the bottom of the vessel containing it will be found to exhibit the dark, shining and characteristic coating of black lead.

Another method will be to pass the washings through a weighed filter, which will retain the black lead which may then be estimated.

Black lead consists principally of carbon, with a variable amount of oxide of iron, usually about 5 per cent.

On the detection of China clay.—The matter entering into the facing of the tea must be removed, as already pointed out, by rapidly washing with cold water, and then obtained from the washings by subsidence. The deposit must be dried, ignited, weighed, and tested first qualitatively and then quantitatively if required, which it rarely will be, for silica and alumina, its two principal constituents. In this case, as in that of silicate of magnesia or soapstone, it will be necessary to fuse the powder with carbonate of potash to effect its decomposition and the formation of a soluble silicate.

On the detection of silicate of magnesia or soapstone.—The powder is collected and decomposed, as before described, and tested for silicic acid and magnesia.

The detection of sulphate of lime or gypsum.—The leaves of tea, especially those from Assam, are sometimes dusted over with sulphate of lime, and this when no other colouring substances are employed.

The sulphate must be separated, as before described, and the ash treated with hydrochloric acid; in the solution, after dilution with water, the sulphuric acid and the lime may be detected and estimated as follows:—One-half of the solution is heated to boiling, chloride of barium is added; this throws down the sulphuric acid as sulphate of barium, which is collected on a filter, incinerated and weighed.

To the other half, neutralised with ammonia and then acidulated with acetic acid, a solution of oxalate of ammonia is added, whereby the lime is precipitated as oxalate of lime, which may be collected and weighed directly or after its conversion into carbonate by incineration, or, better still, into sulphate of lime.

Various other substances have been met with, in years past, entering into the facing of teas of *British fabrication.* Several of these have been already referred to. Others are *Dutch pink*, which consists of a yellow vegetable substance in combination with chalk; *Rose pink*, composed of logwood in combination with carbonate of lime or chalk; *carbonate of lime*, and *carbonate of magnesia.* It is now so rare a thing to meet with the two first-named pigments that it is unnecessary to allude to them any further, while the processes for the detection and estimation of the carbonates of lime and magnesia are too well known to need any description in this place. Moreover, processes will be found given elsewhere in this work.

CHAPTER V.

COFFEE AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Chicory or any other foreign vegetable or any mineral substance.

THE beverage coffee consists of an infusion in boiling water of the roasted seeds of *Coffea Arabica*, which belongs to the natural order *Rubiaceæ*, a plant indigenous in Southern Abyssinia.

Ellis gives the following description of the coffee-tree:—"This tree, when in good health and full grown, attains a height in some countries not exceeding 8 or 10 feet, but in others averaging from 15 to 20 feet. It is covered with a dark, smooth, shining, and evergreen foliage. It is sown in nurseries, transplanted when about six months old, in three years comes into full bearing, and in favourable circumstances will continue to bear for twenty years. It delights in a dry soil and warm situation; its flowers are pale, white, fragrant, and rapidly fading. Its fruit is like that of the cherry-tree, but it grows in clusters; within the fruit are the seeds or berries. On dry and elevated parts the berries are smaller and have a better flavour, but berries of all sizes improve in flavour or ripen by keeping." The seeds are separated by bruising with a heavy roller, washed, and dried, and, lastly, freed from their paperlike coating. The seeds, improperly called berries, of Arabian or Mocha coffee have a more agreeable taste and smell than those of any other coffee, and are distinguished by their yellow colour and comparative smallness and roundness. The next best coffee is from Martinique and Bourbon. The berries of the former are larger than the Arabian coffee, rounded on the ends, of a greenish colour, and usually retain the thin pellicle which comes off by the roasting. The seeds of San Domingo coffee have their two extremities pointed; those of Java or East Indian coffee are larger, and of a paler yellow; while those of Ceylon, West Indian, and Brazilian coffee possess a bluish or greenish-grey tint. The dried fruits or berries are rarely imported. Occasionally, however, the seeds contained in their endocarp, or husks, are met with in commerce. Within the last few years the important fact has been made known that the *leaves* possess to a certain extent many of the properties of the seed, and hence it has been proposed to employ them in this country, as has long been done in the Eastern Archipelago, and especially in Sumatra.

Mr. Ward, resident for many years in Sumatra, states that 'as a beverage the natives universally prefer the leaf to the berry, giving as a reason, that it contains more of the bitter principle and is more nutritious. In the lowlands, coffee is not planted for the berry, not being sufficiently productive, but for the leaf. The people plant it round their houses for their own use. It is an undoubted fact that everywhere they prefer the leaf to the berry.'

THE COMPOSITION OF COFFEE.

The following substances have been ascertained to enter into the composition of the raw coffee-seed:—*Gum, sugar, fat, resin, volatile oil* or *caffeone, theine, caffeic,* or *caffeo-tannic acid* and *cellulose.* The subjoined quantitative analyses are by Schräder and Payen:—

	Raw Coffee. Schräder.	Roasted Coffee. Schräder.
Peculiar caffeic principle	17·58	12·50
Gummy and mucilaginous extract	3·64	10·42
Extractive	0·62	4·80
Fatty oil	0·52	2·08
Resin	0·41	
Solid residue	66·66	68·75
Loss, water	10·57	1·54

Payen's analysis of Raw Coffee.

Cellulose	34·00
Hygroscopic water	12·00
Fatty substances	10 to 13·00
Glucose, dextrin, and undetermined acid	15·50
Legumin, gluten	10·00
Caffeate of potash and caffeine	8·5 to 5·00
Nitrogenous substance	3·00
Free caffeine	0·80
Concrete essential oil	0·001
Aromatic fluid, essential oil	0·002
Mineral substances	6·697

It will be observed that the analysis of Payen is much more complete and definite than those of Schräder; but we have considered it desirable to institute the original analyses of the raw and roasted coffee-seed given below:—

	Raw Coffee.	Roasted Coffee.
Water	8·26	0·36
Cane-sugar	8·18	1·84
Caffeine	1·10	1·06
Fat	11·42	8·30
Gluten	10·68	12·03
Extractive (caramel, gum, tannin, &c.)	14·03	26·28
Cellulose, &c	42·36	44·96
Ash	3·97	5·17
	100·00	100·00

It will be seen from the above analyses that the amount of *caffeine* is nearly as great in the roasted as in the unroasted berry. It is possible, however, that in those cases in which the roasting is carried to a high point, and the beans are much caramelized, a more appreciable reduction in the caffeine would take place. It will be further observed that the amount of *fatty matter* is likewise greatest in the unroasted berry. This result, although contrary to that of other chemists, is yet only in consonance with what might have been reasonably expected, since part of the oil undoubtedly becomes broken up and chemically changed in the process of roasting. The difference in the amount of oil obtained by Von Bibra and other analysts is so great that he was led to the very strange conclusion that the oil was formed in some mysterious manner in the act of roasting; but the real explanation lies in the tough and horny character of the unroasted bean itself, rendering it almost impossible to reduce it to the fine powder necessary to ensure the extraction of all the fatty matter by means of ether. This difficulty we have succeeded in overcoming by rasping the dried berries with a fine file. In this way we obtained an almost impalpable powder, which, however, should be completely dried before adding the ether.

According to Stenhouse, coffee beans contain about 12 per cent. of fat. Von Bibra obtained from roasted Mocha coffee 8·8 and 9·3 per cent., and from Java coffee 8·9 to 9·2 per cent. of oil.

We append a table of estimations of fatty matter in coffee made by ourselves:—

Coffee	8·42
"	8·65
Mysore coffee	8·24
East India coffee	6·10
Jamaica "	7·88
" "	8·30
" " (unroasted)	10·47
Average	8·29

'The fat extracted by ether has the consistency of cocoa-butter, and exhales the peculiar aroma of coffee, which appears to be produced from the volatile oil of the raw beans by roasting; by boiling the fat with water the aroma is driven off. The fat is a mixture of several glycerides, some of which are likewise soluble in alcohol. It appears to contain olein and palmitin, together with resin and some hydrocarbon, perhaps also other bodies. The ethereal extract likewise contains the whole of the free caffeine, and a body which colours iron salts greenish, precipitates lead salts, and reduces gold and silver salts' (Watts).

Messrs. Graham, Stenhouse, and Campbell state that raw coffee contains as much as from 6 to 7 per cent. of *cane-sugar*. We have found over 8 per cent. This is either entirely destroyed in the roasting, or it rarely exceeds 1·12 per cent. The same authorities give the *nitrogen* in roasted coffee as ranging between 2·5 and 3 per cent. Watts gives the proportion of nitrogen in roasted coffee at about 2·75 per cent., and states that less than 2 per cent. of nitrogen in coffee is a strong presumption of adulteration with chicory or some other root. He gives the nitrogen in foreign raw chicory as 1·51 per cent., in the roasted root 1·42 per cent., while English chicory gave in the raw state 1·86, and in the roasted state 1·74 per cent of nitrogen.

The author has obtained the following percentages of nitrogen from four samples of coffee :—

Coffee roasted	2·07
„ „	2·14
Jamaica coffee roasted	2·19
„ „ green	2·14
Average	2·13

During the roasting of coffee the berries swell up, lose much water, and become, according to the extent to which the roasting is carried, from 15 to 25 per cent. lighter; the beautiful and characteristic aroma is developed, the sugar is converted into caramel, carbonic oxide and nitrogen being liberated. Coffee should not be roasted at a temperature exceeding 160° C.

It will be seen that the three most important constituents entering into the composition of coffee are the *volatile oil* called *caffeone*; the *caffeic acid* analogous to the tannin of tea, and *caffeine*, identical with theine.

The *caffeic* acid, like tannic acid, is astringent, but differs from it in that it does not blacken a solution of iron, but renders it green, and does not precipitate a solution of gelatine. This acid, though changed somewhat by the roasting, yet retains to some extent its astringent properties. Like quinic acid, caffeic acid yields quinone when the syrupy extract of coffee is mixed in a retort with binoxide of manganese and sulphuric acid, and the mixture subjected to distillation. The quinone passes over into the receiver in the form of yellow crystals, as well as in that of a bright yellow liquid containing quinone, with much formic acid; quinone is distinguished by its acrid odour, resembling that of chlorine; with ammonia its solution gives a sepia-black colour, converted into reddish-brown by sulphuretted hydrogen, and discharged by sulphurous acid.

Caffeine exists in coffee partly in the free state, and in part combined with the caffeo-tannic acid. It resembles in its colour, crystallisation, solubility in water, alcohol and ether, and in being precipitated from its aqueous solution by tannin, the identical principle theine.

The total amount of caffeine, both free and combined, in coffee is, according to Payen, about 1·736 per cent. This amount is higher than that obtained by other chemists; Parkes puts it down as 1·31 per cent. The average of Boutron's and Robiquet's analysis gave only 0·238 per cent. of caffeine.

Messrs. Graham and Stenhouse obtained from five different samples of raw coffee the following amounts of caffeine:—

Native Ceylon	0·80
" "	0·80
" "	1·01
Plantation Ceylon	0·54
" "	0·83
Average	0·80

We have found the following amounts in seven determinations:—

	Caffeine.
Coffee	1·46
"	1·74
Mysore coffee	1·20
Ceylon "	1·14
Plantation "	1·39
Jamaica "	1·06
" green coffee	1·10
Average	1·30

It thus appears that coffee contains somewhat more than half as much of this alkaloid as does tea, which furnishes an average of over 2 per cent.

Prof. Johnston states that, weight for weight, tea yields about twice as much theine as coffee does to the water in which it is infused, 'but as we generally use a greater weight of coffee than we do of tea in preparing our beverages, a cup of coffee of ordinary strength will probably contain as much theine as a cup of ordinary English tea. One cup of strong French coffee will contain twice as much caffeine as a cup of weak French tea.'

In some countries the grounds of coffee are drunk in the same manner as are the broken leaves of tea, and this with the same object, to obtain all the nourishment, including the nitrogenous substances present in the berry. The two subjoined analyses serve to show the comparative composition of the roasted coffee berry and the tea-leaf:—

	Tea. Mulder.	Coffee. Payen.
Water	5·0	12·0
Gum and sugar	21·0	15·5
Gluten	25·0	13·0
Theine	0·5	0·75
Fat and volatile oil	4·0	13·0
Tannic acid	15·0	5·0
Woody fibre	24·0	34·0
Ash	5·5	6·75

The above analyses must not be relied upon for any other purpose than that of a general comparison. It will be seen that the theine is much understated in the tea.

The proportion of *soluble matter* obtained from coffee is increased by strong roasting. According to Cadet, coffee roasted to a red-brown colour yields 12·3 per cent., chestnut-brown coffee 18·5 per cent., and dark brown 23·7 per cent. of extractive. Payen obtained 37 per cent. Lehmann found in roasted Java coffee 21·5, while Vogel found in the raw beans only 25 per cent., but in the roasted 39 per cent.

The author has obtained the following percentages of extractive matter from various samples of coffee:—

Extractive Matter.

Coffee	25·13
,,	23·17
,,	29·34
Mysore coffee	30·64
East India coffee	30·38
Jamaica ,,	29·43
Average	28·01

Parkes states that it ought to yield from 30 to 35 per cent. of extractive.

The leaves of coffee.—The dried leaves of coffee resemble in composition to a considerable extent the berries, and hence they are employed as a substitute for coffee-seeds and for leaves. A sample of the leaves dried at rather a high temperature was examined by Stenhouse; they were found to contain 1·2 per cent. of caffeine, and 2·1 per cent of nitrogen, and a larger proportion of caffeo-tannic acid than the beans. They yielded to water 38·8 per cent. of extractive matter.

As with tea, it is important to determine in some cases the *amount* and *composition of the ash* furnished by coffee.

The percentage of the ash is shown in the following table:—

Mineral Matter.

	Total.	Soluble.
Coffee	4·75	—
,,	4·50	—
,,	4·17	—
Mysore coffee	4·29	3·53
East Indian ,,	4·07	3·24
Jamaica ,,	4·59	3·71
Average	4·56	3·49

The soluble portion of the ash consists chiefly of phosphate and carbonate of potash. In the case of chicory the proportion of soluble ash is much less than in coffee; while three-fourths of the ash are soluble in the one case, about two-fifths are so in the other.

The following analyses of the ash of coffee are by Messrs. Graham, Stenhouse, and Campbell:—

Analyses of the Ash of Coffee.

	Plantation Ceylon.	Native Ceylon.	Java.	Costa Rica.	Jamaica.	Mocha.	Neilgherry.
Potash . . .	55·10	52·72	54·10	53·20	53·72	51·52	55·80
Soda . . .	—	—	—	—	—	—	—
Lime . . .	4·10	4·58	4·11	4·61	6·16	5·87	5·68
Magnesia . .	8·42	8·46	8·20	8·66	8·37	8·87	8·49
Ferric oxide . .	0·45	0·98	0·73	0·63	0·44	0·44	0·61
Sulphuric acid .	3·62	4·48	3·49	3·82	3·10	5·26	3·09
Chlorine . . .	1·11	0·45	0·26	1·00	0·72	0·59	0·60
Carbonic acid . .	17·47	16·93	18·13	16·34	16·54	16·98	14·92
Phosphoric acid .	10·36	10·60	11·05	10·80	11·13	10·15	10·85
Silica . . .	—	—	—	—	—	—	—
Sand . . .	—	—	—	—	—	—	—
Total . . .	100·63	100·20	99·97	99·06	100·18	99·68	100·04

The principal peculiarities of the ash of coffee are the absence of soda and silica, and the small quantity of chlorine, and of sesquioxide of iron, in all which respects it differs remarkably from the ash of chicory. Watts states that the silica never exceeds 0·5 per cent., and even this small quantity, which is not always present, probably arises from accidental adhesion of sand to the beans. Chicory ash, on the other hand, contains, deducting sand, from 3·81 to 10·52 per cent. of silica.

THE PROPERTIES OF COFFEE.

Pereira thus sums up the properties of the infusion of the roasted coffee-seeds:—'Roasted coffee possesses powerful anti-soporific properties—hence its use as a drink by those who desire nocturnal study, and as an antidote to counteract the effects of opium and other narcotics, and to relieve intoxication. In those unaccustomed to its use it is apt to occasion thirst and constipation. On some persons it acts as a slight purgative. It is occasionally useful in relieving headache, especially the form called nervous. It has been employed as a febrifuge in intermittent and as a stomachic in some forms of dyspepsia, and as a stimulant to the cerebro-spinal system in some nervous disorders. Flayer, Dr. Percival, and others have used it in spasmodic asthma, and Laennec says: "I have myself seen several cases in which coffee was really useful." The immoderate use of coffee is said to produce nervous symptoms, such as anxiety, tremor, disordered vision, palpitation, and feverishness.'

Coffee is also supposed to counteract the tendency to the formation of gravel and stone.

The properties and effects of coffee are thus described by Professor Johnstone :—'It exhilarates, arouses, and keeps awake. It counteracts the stupor occasioned by fatigue, by disease or by opium; it allays hunger to a certain extent, gives to the weary increased strength and vigour, and imparts a feeling of comfort and repose. Its physiological effects upon the system, so far as they have been investigated, appear to be, that while it makes the brain more active, it soothes the body generally, makes the change and waste of matter slower, and the demand for food in consequence less. All these effects it owes to the conjoint action of three ingredients very similar to those contained in tea.'

The volatile oil.—When roasted and ground coffee is distilled with water the volatile aromatic oil passes over, and by drinking this oil with water its effects may be ascertained. When the oil obtained from two ounces of coffee is taken in a day, it is found to produce an agreeable excitement and gentle perspiration, to dispel the sensation of hunger and to move the bowels. 'In its exhilarating action upon the brain it affects the imagination less than the reasoning powers' (Johnston). When the dose of oil was doubled violent perspiration came on with sleeplessness and symptoms of congestion. Lehmann, by a series of careful observations and experiments on the urine, ascertained that it exercised an effect equal to that of caffeine in retarding the waste of the tissues.

The caffeic acid.—Messrs. Graham and Stenhouse state that chemists generally are disposed to refer the flavour and peculiar properties of coffee as a beverage more to the caffeic acid, particularly after that substance is modified in its properties by roasting, than to any other constituent. The quantity present is much less than the tannin in tea, and consequently coffee does not retard to the same extent the action of the bowels, its operation being furthermore counteracted by the volatile aromatic oil which exerts an aperient tendency.

Caffeine.—It has been already stated that the caffeine is identical with theine, the action of which on the system has been before described. In Pereira's 'Materia Medica' we meet with the following observations relative to the properties of caffeine:—'Mulder gave a grain to a rabbit; the animal ate but little the next day, and aborted the day after. Liebig has suggested that it probably contributes to the formation of taurine, the nitrogenised constituent of bile. According to Lehmann caffeine, in doses of from 2 to 10 grains, causes violent excitement of the vascular and nervous systems, palpitation of the heart, extraordinary frequency, irregularity, and often intermission of pulse; oppression of the chest, pains in the head, confusion of the senses, singing in the ears, scintillations before the eyes, sleeplessness, and delirium. In all cases an augmentation was found in the amount of urea excreted.'

THE ANALYSIS OF COFFEE.

The analyst may have to determine either the composition of the raw or roasted seed. In either case it will be necessary that it be previously reduced to a fine powder, and in the case of the roasted berry it is best that the analysis should be made while it is in its freshly-roasted state.

The following determinations will in most cases be required to be made :—Water, fat, sugar, gluten, volatile oil, caffeic acid, theine, and the ash.

Many of the requisite particulars and processes will be found described under the head of the analysis of tea, so that it will not be necessary to give them all fully in this place. Thus, the water is estimated in the usual manner by drying, the gluten by the estimation of the nitrogen by the combustion process, the volatile oil by distillation, the theine by one or the other of the processes given under the head of tea, and the mineral matter by incineration.

But since the coffee berry contains so large a quantity of oily matter, it becomes necessary to filter the aqueous solution of the extractive matter prior to its evaporation for the estimation of caffeine.

We have thus only to describe the methods for the estimation of the fixed oil, the sugar, and the caffeic acid.

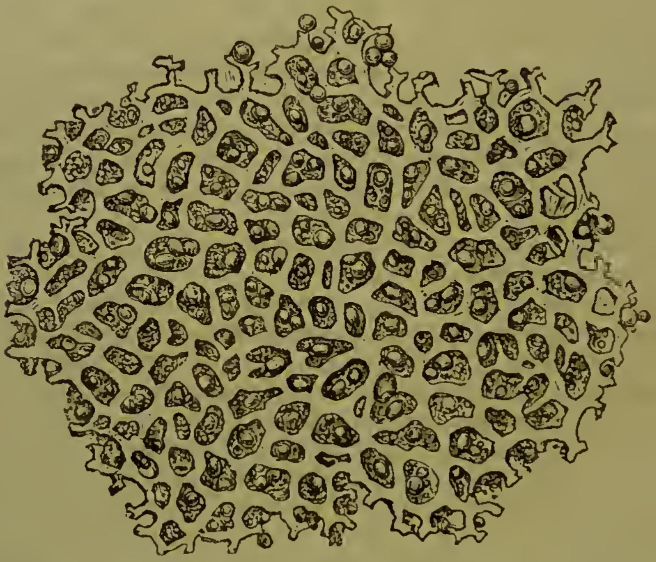
Estimation of the fixed oil.—A weighed quantity of the finely-ground coffee, say three grammes, is dried in the water-bath in a small flask and exhausted by repeated quantities of ether until a few drops of the solution, when evaporated on a slip of glass, cease to leave any residue. The ethereal solutions are evaporated in a flask, the weight of which has been determined, after which the flask is again weighed, the difference giving the quantity of fat present in the coffee. Or the weight of the exhausted coffee may be taken, and the deficiency will of course represent the amount of fat. Part of the caffeine is always dissolved by the ether, together with the fat, and may be separated by digestion with hot water.

Estimation of sugar.—Owing to the fact that the copper solution is reduced by the caffeic acid, the sugar after its conversion into glucose cannot be estimated in coffee in the ordinary way, but it must be converted into alcohol and estimated in this form. About 150 grammes of the ground coffee are to be treated with separate quantities of cold or warm water. To the solution, after filtration, sufficient yeast is added to induce fermentation; this is to be continued for 48 hours, the infusion being kept at a temperature of from 27° to 32° C. The liquid is to be distilled nearly to dryness ; the quantity, as well as the specific gravity, of the distillate being taken, and the sugar determined from the quantity of alcohol thus formed. 92 parts of alcohol are equal to 180 parts of glucose. Or the caffeic acid may be precipitated by means of acetate of lead and the sugar determined in the filtrate in the usual manner after conversion into glucose by means of dilute sulphuric acid.

ON THE STRUCTURE OF THE COFFEE-SEED.

Two parts are to be discriminated in the coffee berry; the substance of the berry, and the testa or covering by which it is surrounded. The berry previous to roasting is hard and tough; it consists of an assemblage of cells of an angular form, which adhere so firmly together that they break up into pieces rather than separate into perfect cells. The cavities of these cells include in the form of little drops a considerable quantity of oily matter. (Fig. 32.)

Fig. 32.



Section of UNROASTED COFFEE BERRY, showing the size and form of the cells, as well as the drops of oil contained within their cavities. Drawn with the Camera Lucida, and magnified 140 diameters.

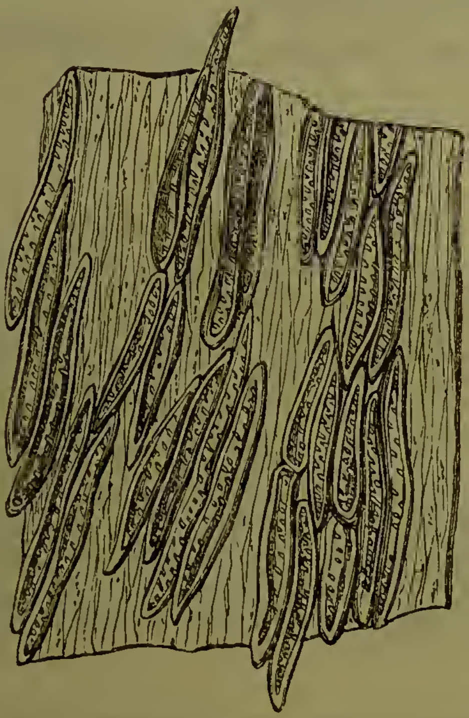
The testa or investing membrane is made up principally of elongated and adherent cells, forming a single layer, and presenting oblique markings on their surfaces. These cells rest upon a thin membrane having an indistinct fibrous structure. Between the berry and its covering some oily matter is usually present. (Fig. 33.)

The removal of this membrane may be easily effected, since in the act of roasting it becomes separated from the berry, when it is known by the name of 'coffee-flights.'

In the grove or 'raphe' which runs along each seed, a few small double spiral vessels are usually met with.

The roasting of the seed does not alter its structure; the tissues are indeed partially charred, but they still preserve their chief characteristics. The oil, however, is no longer visible in the cells in the form of minute spherules, it having become broken up and diffused by the heat employed in the process of roasting. (Figs. 34 and 35.)

Fig. 33.



A portion of the INVESTING MEMBRANE of the Coffee Berry, showing its structure. Drawn with the Camera Lucida, and magnified 140 diameters.

ON THE ADULTERATIONS OF COFFEE.

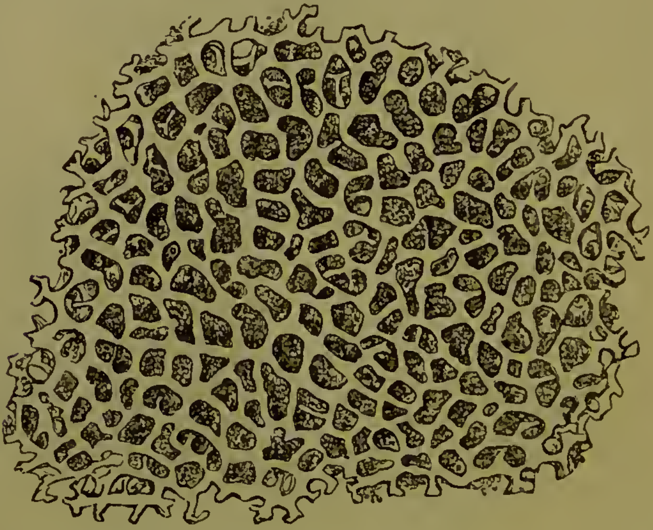
Some years since there were few articles of consumption more subject to extensive adulteration, and this of the grossest kind, than coffee. At the time when we first directed our attention to the adulteration of coffee it was scarcely possible to procure a sample of ground coffee, no matter what the price paid for it, that was not largely adulterated.

Adulteration with chicory.—The most prevalent adulteration of coffee is with chicory. In nearly all the samples examined some years since, chicory formed a large proportion of the article, while in many instances it consisted almost entirely of chicory. At the present time coffee is still much adulterated with chicory, while the compound sold with the labels now prescribed by the law—'This is a mixture of chicory and coffee'—often consists of little else than chicory.

Even the grinding of the coffee in the presence of the purchaser is said to be no certain guarantee of the genuineness of the article, as not unfrequently the grocer adroitly conveys into the mill, from a box placed close to it, as many chicory nibs as he pleases, and which, owing to their resemblance in size and colour to coffee berries, are not readily distinguished at a short distance.

Even whole roasted coffee has been adulterated with chicory, which in this case is compressed into the form of coffee-seeds. In 1850, Messrs. Duckworth, of Liverpool, took out a patent for moulding chicory into the shape of coffee-seeds. They appeared to have been induced to do so in consequence of the existence in 1850 of a Treasury Minute, which allowed the sale of chicory with coffee without any restriction.

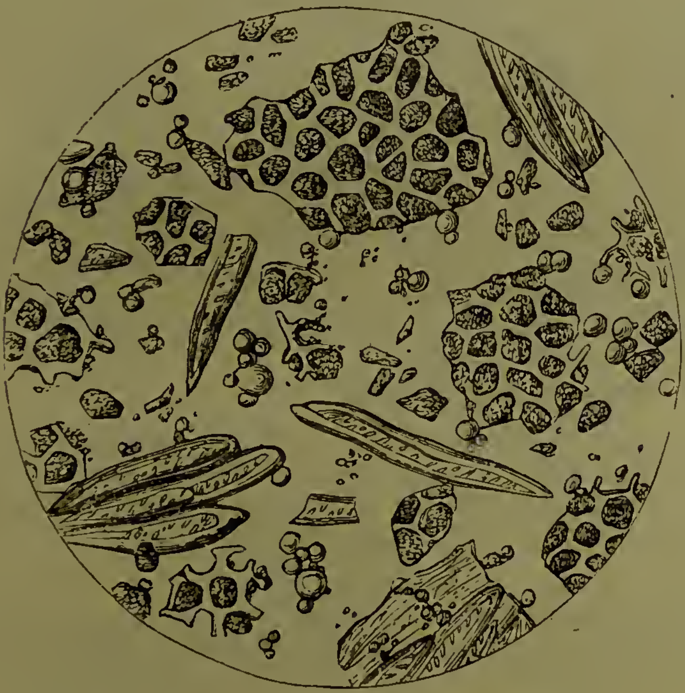
Fig. 34.



A fragment of Roasted Coffee. Drawn with the Camera Lucida, and magnified 140 diameters.

It has been strenuously urged, in extenuation of this adulteration, that the addition of chicory to coffee is a great improvement. There are undoubtedly some few persons who do consider that it does improve the flavour, but we believe that the taste of those who really prefer the mixture has been vitiated, and that had they the opportunity of obtaining well-prepared and unadulterated coffee, they would speedily acknowledge the infinite superiority of the genuine beverage, even as a matter of taste. When the relative properties of coffee and chicory are taken into account, no doubt whatever can be entertained as to which is the superior article; Chicory being destitute of the three prime constituents—the volatile oil, the caffeine, and the caffeic acid, which impart to coffee its peculiar, beneficial, and highly characteristic properties. It has been affirmed that in France and in other continental countries the use of chicory is almost universal. We have found that in all the good hotels in France and Germany the coffee served up has been genuine, and that where chicory has been employed, either separately or mixed with coffee, it has been by poor persons and amongst the domestics, not because it was considered to be an improvement, but on the score of economy. Where money is not an object, and where the best coffee is required, chicory is but seldom had recourse to. Again, if really an improvement, as some persons consider, it would only be so when employed in certain proportions. Now, in the ground coffee sold in the shops of this country, it is met with in every proportion, it constituting sometimes over 90 per cent. of the article. The allegation that chicory improves the flavour of coffee would not warrant its use to anything like this extent.

Fig. 85.



This engraving exhibits the characters of *genuine ground* COFFEE.

It cannot, therefore, be doubted for a moment that the real cause of the extensive employment of chicory in this country is that by its means grocers are enabled to enhance greatly their profits. But we will suppose, for the sake of argument, that it is a decided improvement; yet this does not justify the sale of a mixture of chicory and coffee as and under the name of coffee, coffee frequently forming but a small percentage of the article. Such a mixture, if permitted at all, should not only be labelled as a mixture, but the proportions of each ingredient should be specified.

Few persons will be disposed to question the right of the purchaser when he enters a shop, and asks for a particular article, to expect that he will be supplied with the article he demands, and that if he asks for coffee he will be supplied with coffee, and not with a mixture of two articles in the most uncertain proportions. Let the two substances, therefore, be sold separately and at their respective prices. This is the simple and straightforward course to pursue.

At length, and after years of labour and argument, the Government was driven to acknowledge the impropriety of permitting chicory to be sold under the name of coffee, and frequently also at the price of that article, and within the last few years it has been required that the mixed articles should be sold labelled 'This is a mixture of chicory and coffee.' But this regulation by no means fulfils the requirements of justice, because the mixture is often palmed off when coffee only is asked for, and because the proportions of the ingredients are not stated.

But there is one circumstance which has been already adverted to, and which should be particularly remembered in considering the question of the adulteration of coffee with chicory—namely, the differences, chemical and physiological, which exist between the two articles.

Coffee and chicory contrasted.—Coffee is the seed of a plant which in its roasted condition contains essential oil, or caffeone, caffeine, and caffeic acid, each of these constituents possessing highly important properties upon which the value of coffee mainly depends. Chicory is the root of a plant; it contains neither essential oil, tannic acid, nor an alkaloid analogous to that of coffee, it consisting chiefly, when roasted, of gum, sugar, partly burnt and reduced to caramel, and insoluble vegetable tissue. Between the two articles, therefore, there is no analogy whatever, and in proportion as the strength of coffee is reduced by admixture with chicory, so are the active properties of the beverage diminished.

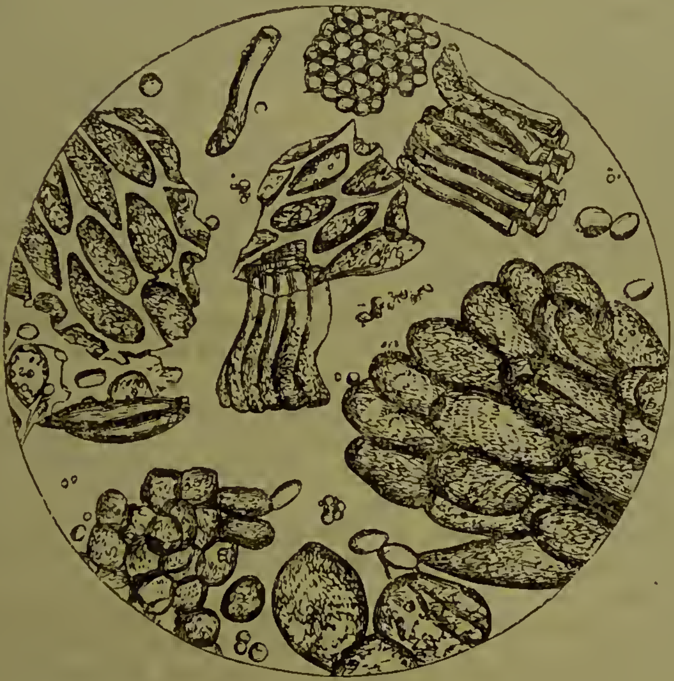
It is the presence of these active constituents of coffee, and which are contained in tea, and also cocoa, which has led to the almost universal employment of these articles over nearly the whole of the inhabited portions of the globe.

But coffee is subject to adulteration with a variety of other articles besides chicory.

Adulteration with roasted grain. — The adulteration which was formerly most frequently practised next to that with chicory was with roasted grain, principally *wheat*, but *rye* and roasted *peas* and *beans*, ground into powder, were also not unfrequently met with.

Adulteration with roasted roots.—Roasted *carrots, parsnips*, and *mangold wurzel*, reduced to powder, were also frequently employed for the adulteration of coffee.

Fig. 36.



This engraving exhibits the several structures detected in a sample of 'COFFINA.' Drawn with the Camera Lucida, and magnified 140 diameters.

Other articles which have been ascertained to be used for the same purpose, and most of which we have ourselves encountered, are roasted *acorns, sawdust* (especially mahogany sawdust), *coffina* (fig. 36) (an article made from roasted and ground *lupin seeds*), *oak bark tan, exhausted tan*, termed *croats*, and *baked horses' liver*.

Adulteration with baked liver.—In a work published now many years since, entitled 'Coffee As It Is, and As It Ought to Be,' the following observations occur in reference to the use of baked horses' and bullocks' livers:—'In various parts of the metropolis, but more especially in the east, are to be found liver bakers. These men take the livers of oxen and horses, bake them, and grind them into a powder which they sell to the low-priced coffee-shop keepers at from 4*d*. to 6*d*. per pound, horses' liver coffee bearing the highest price.' It may be known, the writer states, 'by allowing the coffee to stand until cold, when a thick pellicle or skin will be found upon the top; it goes further than coffee, and is generally mixed with coffee and other vegetable imitations of coffee.'

Adulteration with burnt sugar.—The adulteration of coffee in some cases so greatly alters, and reduces the colour and appearance of the article as well as the infusion made from it, that the use of colouring matters is frequently necessitated. One of these is *burnt sugar*, familiarly known in the grocery trade and by coffee-shop keepers as 'Black Jack.' It is sold to the coffee-shop keepers usually in canisters at 1*s*. per pound, and it is sometimes denominated 'The Coffee Refiner.' It is, however, rather a colouring agent, and is employed to impart colour and bitterness to beverages made from adulterated coffee, these being the qualities which, in the eyes of superficial observers, denote strength and goodness.

Sugar is sometimes added to the coffee-seed while undergoing the process of roasting, and being then burnt, is converted into a coffee colourer.

Adulteration with Venetian red.—Another article used to give increased colour to adulterated ground coffee is *Venetian red*, or some other analogous ferruginous earth. We have not only ourselves obtained repeated evidence of the use of this substance, but we shall presently, under the head of 'Chicory and its Adulterations,' quote a passage from the writings of the late Dr. Pereira in reference to its employment.

In the latter part of 1850 the author read a communication to the Botanical Society of London on the adulteration of coffee, that being some months before the publication of the first of his reports in the 'Lancet' on Adulteration. In this the author described for the first time the results at which he had been enabled to arrive from the examination of coffee by means of the microscope, this being one of the first instances of the employment of that instrument for the detection of adulteration. These results were as follows:—

First, That, of the *thirty-four* coffees examined, *thirty-one* were adulterated.

Second, That chicory was present in *thirty-one* of the samples.

Third, Roasted corn in *twelve*.

Fourth, Beans and potato flour each in *one* sample.

Fifth, That in *sixteen* cases the adulteration consisted of chicory only.

Sixth, That in the remaining *fifteen* samples the adulteration consisted of chicory and either corn, beans, or potatoes.

Seventh, That in many instances the quantity of coffee present was very small, while in others it formed not more than one fifth, a fourth, third, half, and so on of the whole article.

On some of the foregoing adulterated samples the following high-sounding names had been bestowed:—*Delicious Coffee*, containing *beans* and *chicory*; *Finest Turkey Coffee*, much *chicory roasted corn* and very little coffee; *Finest Java Coffee*, much *roasted corn* and a little *chicory*; *Parisian Coffee*, principally *chicory* and *roasted corn*; *Superb Coffee*, principally *roasted corn* and *chicory*; *Delicious Family Coffee*, three-quarters *chicory*; *Delicious Drinking Coffee*, a large quantity of *chicory* and much *roasted corn*.

We are satisfied that the gross aggregate of the adulterations detected did not amount to less than one-third of the entire bulk of the quantity purchased.

On referring to the Revenue returns of that period we find that the sum derived from the duty on coffee was nearly 45,000*l.*, an amount which we have no hesitation in saying might have been greatly increased by vigilance in the detection of the adulterations of this important article, and by punishment of the fraud, when detected.

Since the date above referred to, the author has examined some hundreds of samples of ground coffee, the particulars of which will be found recorded in his work entitled 'Food and its Adulterations.' Until within the last two or three years, we have always found a large proportion of the samples to be adulterated; more recently, however, the condition of the article has greatly improved. The grosser adulterations, so far as the metropolis is concerned, are now much less frequently practised. The principal adulteration now is that with chicory, which is still mixed with coffee, and sold without the prescribed label as coffee. This improved state of things is undoubtedly due to the repeated exposures made within the last few years. But is it not perfectly certain, if these exposures were to cease, that matters would soon become worse than before, and that the scandalous and nefarious practices which once prevailed in the adulteration of the article would speedily be rife again?

The adulterations by means of roasted corn, beans, coffee colourer, and Venetian red are altogether indefensible, since the only thing in common between most of these and coffee is the colour which they yield on infusion or decoction.

Many years since roasted corn, principally rye, was largely sold and employed to make a beverage which, by a fiction, was dignified with the name of coffee; the chief argument, independent of price, urged in favour of it was its supposed nutritive properties. When it is recollected that the starch of roasted corn is in part reduced to the condition of charcoal, it will at once be perceived that its nutritive qualities cannot be very great, and that a single mouthful of wholesome bread contains more nourishment than half-a-dozen cups of a beverage made from roasted corn. Although 'roasted corn' is now no longer sold openly, yet, as we have seen, the grocer has not failed to avail himself of it for his own benefit, and to the great disadvantage of the public.

The adulteration of coffee by substances so cheap, and for the purpose to which they are applied so worthless, as these is a gross fraud, requiring emphatic condemnation, and when ascertained to be practised, meriting exposure and punishment.

Other adulterations of coffee.—According to Watts, 'a great variety of seeds were tried in France during the continuance of the continental blockade, including, amongst others, the *yellow flag*, *chick-pea*, the *milk vetch*, the *holly*, *Spanish broom*, *chestnut*, *lupin*, *sunflower*, *gooseberry*, *grape*, *eglantine*, *capsules of box*.' 'The poorer sorts of coffee-beans are sometimes tinted by dusting them with coloured powders, such as *Prussian blue*, *powder of lime-tree charcoal*, *green earth*, mixed with a little *graphite* to give them the silvery appearance of the finer sorts.' Watts also names amongst the adulterants of coffee *beet-root*, *rushnut*, *earthnut*, *scratchweed*, *fern*, and *butcher's broom*.

We have never met with any one of the adulterants above enumerated, and we are satisfied that their use in this country is but rarely, if ever, resorted to. We do not, therefore, propose to encumber this treatise with any description of the methods whereby they may be discriminated.

ON THE DETECTION OF THE ADULTERATIONS OF COFFEE.

The means to be resorted to for the detection of the adulterations of coffee are of three kinds—namely, the physical characters and appearances presented by adulterated samples, the microscope, and chemistry. By the first, we ascertain in some cases the general fact whether the sample is adulterated or not; and by the others, especially by the microscope, we learn the nature of the particular adulterations practised.

The first means consist in noticing whether the sample in the mass cakes or coheres, whether it floats in water or not, and the colour of the infusion.

If the ground coffee cakes in the paper in which it is folded or when pressed between the fingers, there is good reason for believing that it is adulterated, most probably with chicory.

If, when a few pinches of the suspected coffee are placed upon some water in a wine-glass, part floats and part sinks, it may be presumed that it is adulterated either with chicory, roasted corn, or some other analogous substances. The coffee does not imbibe the water, but floats on the surface, while the other substances absorb the water, and gradually subside to the bottom to a greater or less extent. Usually, however, part of the coffee subsides with the chicory, and a portion of the latter remains on the surface with the coffee; and after the lapse of a short time, in general, both coffee and chicory fall to the bottom.

Again, if the cold water to which a portion of ground coffee has been added quickly becomes deeply coloured, it is an evidence of the presence of some roasted vegetable substance or burnt sugar; for when coffee only is added to water, it becomes scarcely coloured for some time. Again, not only does the solution become dark coloured, but if a boiling aqueous solution be made, it will be thick and mucilaginous if it be adulterated with any substance containing much gum and starch, but the infusion of coffee will be found thin and limpid.

According to Watts, chicory has more than three times the colouring power of highly-roasted coffee, maize double that of coffee, while peas and beans have only half the colouring power. In infusions prepared with cold water, chicory exhibits four times the colouring power of coffee.

Lastly, if in a few grains of coffee, spread out on a piece of glass and moistened with a few drops of water, we are enabled to pick out, by means of a needle, minute pieces of a substance of a soft consistence, the coffee is doubtless adulterated; for the particles of the coffee-seed are hard and resisting, and do not become soft even after prolonged immersion in water.

When, therefore, any sample cakes into a mass, quickly furnishes to cold water a deep-coloured solution, or is found to contain, when moistened with water, soft particles like those of bread-crumb, there can be no question as to the existence of adulteration.

The characters of genuine ground coffee are, therefore, the reverse of the above.

By these general means, and without having recourse to science, the observer is often enabled to state whether any sample of coffee is adulterated or not; but in order to determine the character of the adulteration practised, we must employ either the microscope or chemistry. In the case of coffee, by far the most important information is furnished by the microscope; indeed, chemistry affords no certain means for the identification of the majority of the vegetable substances employed in the adulteration of coffee, and did it do so, it would hardly be required, since these may be so readily detected by the microscope.

Messrs. Graham, Stenhouse, and Campbell have instituted some special chemical inquiries on the mode of detecting vegetable substances mixed with coffee: these will be found referred to at some length under the article 'Chicory.'

The result of these investigations is, that it is easy enough to ascertain by means of chemistry the general fact of adulteration, but that it is not possible by the same means to determine the nature of the adulteration practised, even that with chicory.

One method of discriminating whether a coffee be genuine or adulterated is by means of *the specific gravity of the infusions*, the specific gravity of an infusion of coffee being much less than that obtained from the roots and cereals employed in the adulteration of coffee. But the infusions obtained from the leguminous seeds have a specific gravity very closely approaching that of coffee itself. If one part of the substance be boiled with ten parts of water, and the specific gravity of the filtered solution be taken, the following figures represent the different specific gravities:—

Acorns	1007·3
Peas	1007·3
Beans	1008·4
Coffee (average)	1008·7
Parsnips	1014·3
Carrots	1017·1
Maize	1021·5
Rye	1021·6
Beet-root	1022·1
Chicory (average)	1024·8
Mangold-wurzel	1023·5
Bread raspings	1026·3

A further means of distinguishing between pure coffee and that adulterated with chicory and many other roots is by *the quantity of sugar* contained in them both before and after torrefaction. The amount of sugar is, of course, much greater in these roots, and is determined in the infusions by fermentation with yeast and the estimation of the alcohol in the distillate.

The sugar in raw coffee varies from 7·52 to 8·2 per cent.; that of roasted coffee from 0·0 to 1·14 per cent. The following percentages of sugar in chicory and other sweet roots have been found:—

	Raw.	Roasted.
Foreign chicory	23·76	11·98
Guernsey „	30·49	16·96
English „	35·23	17·98
Yorkshire „	32·06	9·86
Mangold-wurzel	23·68	9·96
Carrots (ordinary)	31·98	11·53
Turnips	30·48	9·65
Beetroot (red)	24·06	17·24
Parsnips	21·70	6·98

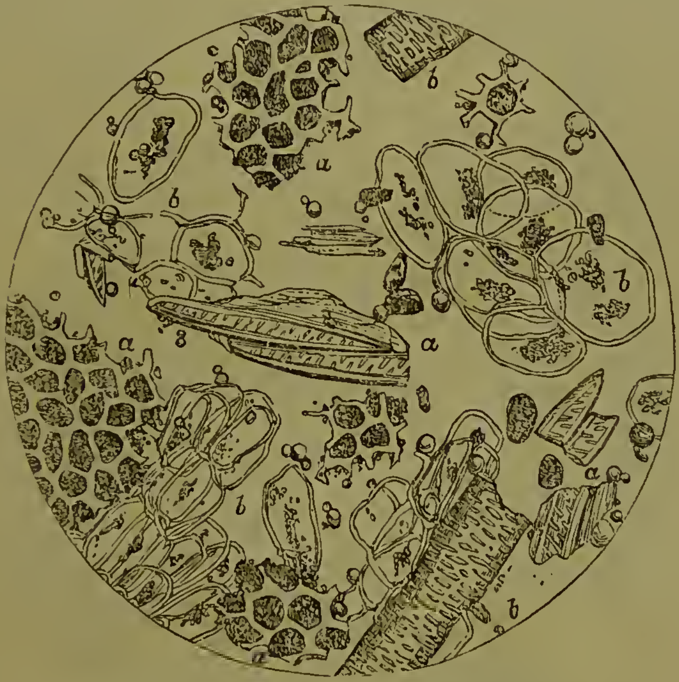
The above figures are sufficient to show that the sweet roots may as a class be thus readily distinguished from coffee, but for the determination of the particular kind of root present recourse must be had to the microscope.

In the leguminous seeds, cereals, and some other seeds, the proportion of sugar is much less, and hence this method of discrimination fails in these cases.

The most distinctive peculiarity of the composition of the ash of coffee is the small quantity of *silica* contained in it: 'the presence.' state Messrs. Graham and Stenhouse, 'of 1 per cent. or upwards of silica in the ash of coffee is a proof of adulteration; that the adulterating substances which increase the proportion of silica most considerably are oats and barley, then chicory and dandelion, which are followed by rye and wheat; but turnips and carrots would produce a small and less decisive effect.'

We presume that Messrs. Graham and Stenhouse, in the preceding paragraph, refer only to the silica entering into the composition of the several vegetable substances named, and not to that accidentally present, which in the case of chicory and other roots often amounts to several percentages.

Fig. 37.



Shows the structures in a sample of COFFEE *adulterated with* CHICORY.
a a, coffee; *b b*, chicory.

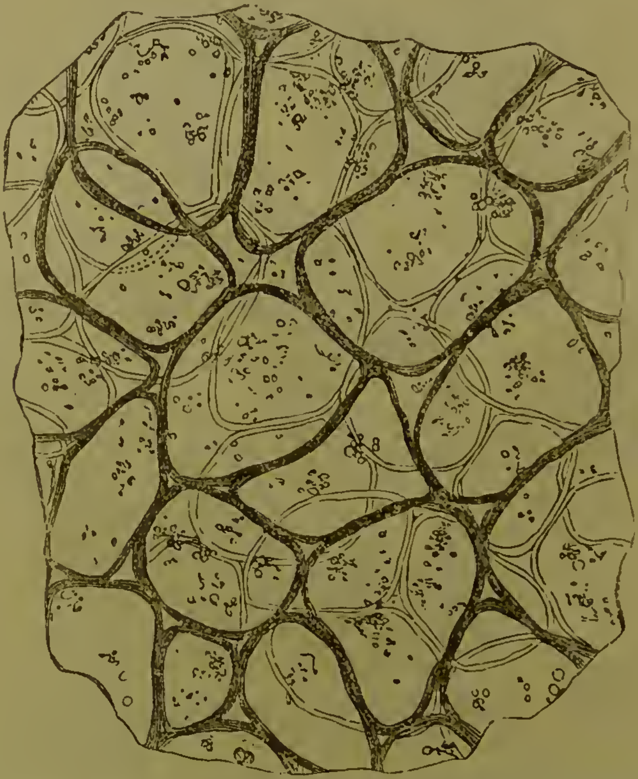
The general fact of adulteration may, therefore, be determined in a variety of ways; as, by the colour of the infusion, by its specific gravity, by the quantity of *sugar* contained in it, and, lastly, by *the composition of the ash.*

We will now again shortly enumerate the articles which have been detected entering into the adulteration of ground coffee. They are roots of different kinds, particularly chicory, mangold-wurzel, carrot and parsnip, various farinaceous substances in the roasted and powdered state, as wheat and rye flour, beans, and acorns; besides these are woody fibre or sawdust, burnt sugar, and Venetian red or reddle.

We will now proceed to give the methods employed for the detection of the principal of the above adulterations.

On the detection of chicory.—Some years since, an outcry having arisen in consequence of the substitution to an enormous extent of chicory for coffee, and the Government being called upon to interfere, the question as to whether the presence of chicory in ground coffee

Fig. 38.



This figure exhibits the cells of which the root of MANGOLD-WURZEL is chiefly formed; it will be observed that they are several times larger than those of chicory root.

was discoverable or not by means of science was referred by the Chancellor of the Exchequer of the time to a commission of chemists.

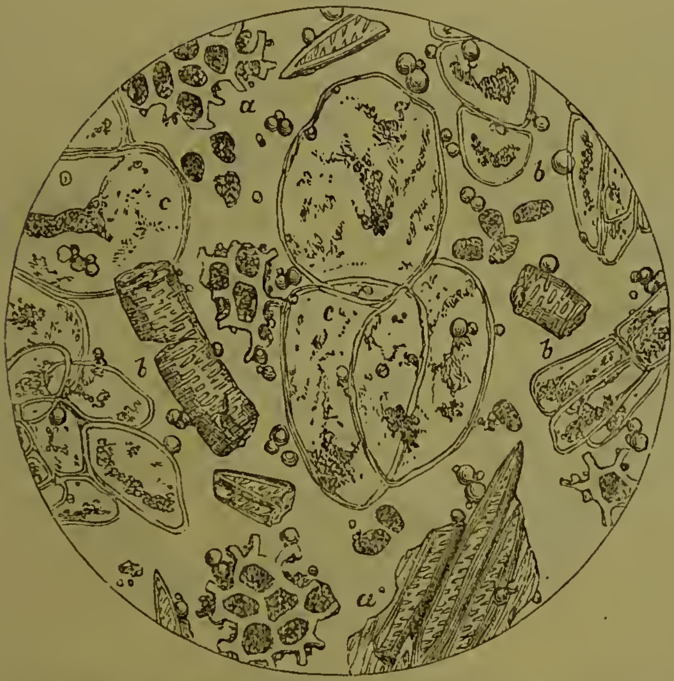
These chemists reported, that 'neither by chemistry nor by any other means was the admixture of chicory with coffee to be detected.' This report was publicly quoted by Sir Charles Wood in the House of Commons, and on the strength of it the Government refused to interfere in the prevention of the adulteration of coffee. Now, just before that time the author had shown, in the most conclusive manner, that nothing is more easy and certain than the detection of chicory in coffee by means of the microscope.

The structure of coffee has already been fully described; that of chicory will shortly be considered; it may be stated now, however, that it differs in every respect from coffee, in the rounded form and easy separability of its component cells, and in the presence of dotted ducts, and *vasa lacticentia.*

The differences will be sufficiently obvious on an examination of the accompanying figures.

Detection of mangold-wurzel.—This root differs from chicory in the very much larger size of the cells, and in the absence of milk vessels or vasa lacticentia (figs. 38 and 39).

Fig. 39.

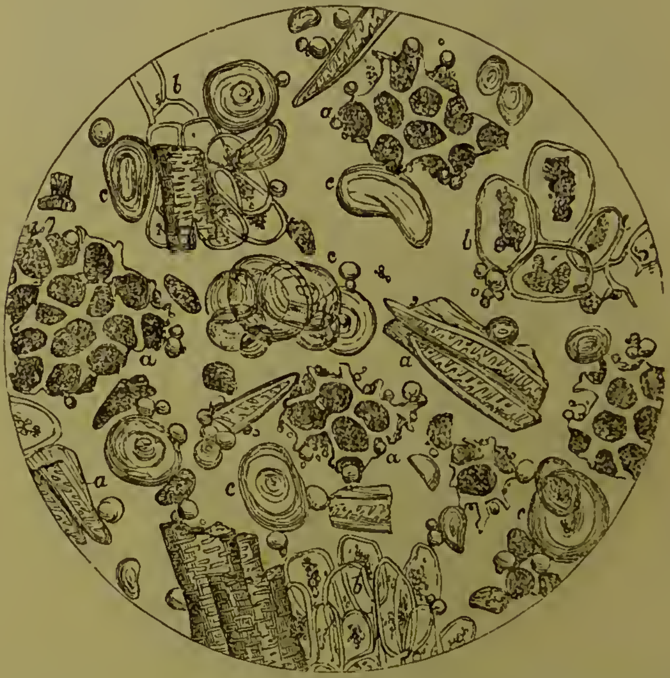


Shows the structures met with in *Coffee adulterated with* MANGOLD-WURZEL. *a a*, fragments of the coffee berry; *b b*, cells of chicory; *c c*, ditto of mangold-wurzel.

Detection of carrot and parsnip.—The tuber of carrots differs from chicory chiefly in the absence of milk vessels; that of parsnip in the absence of the same vessels, and in the presence in the cells of regularly formed starch corpuscles of small size.

On the detection of wheat-flour, &c.—It is generally stated that the presence of roasted corn or any other substance containing a large proportion of starch, may be detected by the blue colour produced on the addition of a solution of iodine to the cold decoction. We have not found this to be correct in all cases, for on adding iodine to decoctions of five different coffees ascertained to be adulterated with roasted corn, the liquids did not become blue, but almost black, with a tinge of brown or olive. This appears to arise from the obscuration of the blue colour developed by the iodine, by the rich brown colouring matter of the chicory—a proportion of which almost always accompanies the adulteration with corn. This test, however, is still very useful in some cases, although it does not often give rise to a colour which can be called blue. It should be known, also, that solution of iodine, added to a cold decoction of chicory root, deepens the colour very greatly: the increase of colour is never, however, so considerable as when flour is present.

Fig. 40.



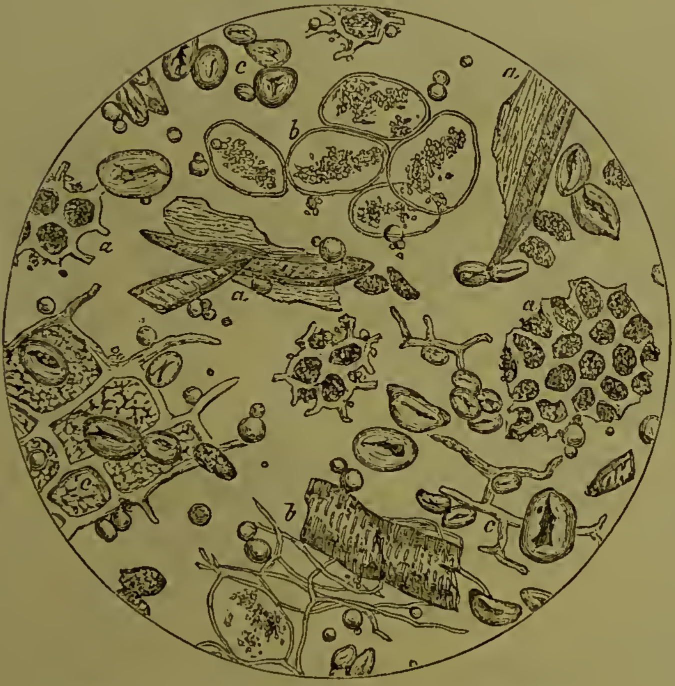
Sample of *Coffee adulterated with both* Chicory *and roasted* Wheat.
a a, coffee: *b b*, chicory; *c c*, wheat flour.

It is to be further observed that no exact idea can be formed in this way of the quantity of starch contained in the adulterated coffee, because part, being charred, gives no reaction with iodine.

Supposing, however, that the presence of starch in coffee could be invariably detected by the iodine test, yet neither that test, nor indeed all the resources of chemistry, can furnish us with precise information as to the kind of starch employed. For this we must seek the aid afforded by the microscope.

The microscopical structure of wheat and certain other flours will be found described under the heads Flour and Bread. They are distinguished chiefly by the characters of the starch corpuscles. It may be stated, generally, that those of wheat consist of rounded and flattened discs of various sizes. The appearances which they present are very distinct from the cells of either coffee or chicory, as will be seen by the annexed engraving (fig. 40).

Fig. 41.



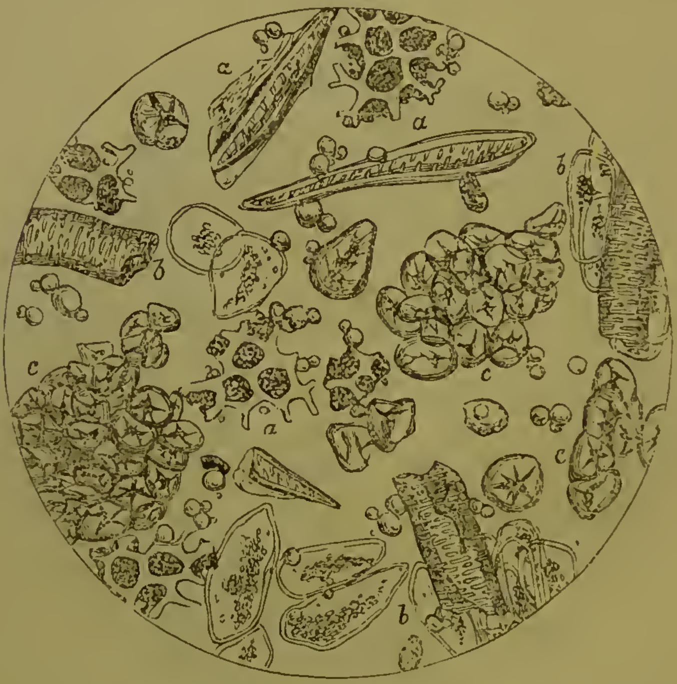
Coffee adulterated with both CHICORY *and roasted* BEANS.
a a, coffee; *b b*, chicory; *c c*, roasted bean flour.

On the detection of bean-flour.—The substance of the seed of the bean is made up of cells, each of which contains several starch corpuscles. The characters of these granules are very distinctive; they are for the most part either oval or reniform, with a central cavity of an elongated form, and from the margin of which short rays or processes may be seen radiating. So long is this cavity, in some of the granules of medium size, that they appear to be completely bisected; occasionally a few strongly marked concentric rings are visible. Some of these characters are exhibited in fig. 41.

On the detection of roasted and ground acorn.—The presence of this substance is distinguished by the form and size of the starch corpuscles, which constitute so large a part of the acorn (fig. 42).

On the detection of sawdust.—The detection of sawdust, especially mahogany sawdust, is extremely easy; the presence of woody fibre of some kind or other is sure to be discovered when the suspected samples come—as they always ought—to be examined with the microscope. The presence of sawdust having been thus ascertained, a few grains of the coffee should be spread out on a slip of glass, and moistened with water, when the fragments of woody fibre may generally be picked out by means of a needle; they should then be subjected to a more careful microscopical scrutiny.

Fig. 42.



Sample of *Coffee adulterated with ground* ACORN. *a a*, coffee; *b b*, chicory; *c c*, acorn.

The woody fibre of plants, like the cellulose, starch corpuscles, and vessels, frequently possesses distinctive characters, visible under the microscope, by which the plant or tree furnishing it may be identified.

In the case of mahogany sawdust the identification is easy enough: the compactness of the little masses of fibre, the strong cross markings, and the colour are sufficiently characteristic.

It should be remembered that chicory, especially the older roots, contains a small proportion of woody fibre, so that care must be exercised not to confound this fibre with extraneous woody fibre or sawdust introduced for the purpose of adulteration. If the quantity of fibre present be very small, and it agree with that of chicory in its structure as seen under the microscope, there can be little doubt but that the fibre belongs to the root of chicory.

On the detection of caramel or burnt sugar.—When the water added to any sample of ground coffee becomes deeply and quickly coloured, and when on examination with the microscope it is ascertained that no foreign vegetable is present, there will be good reason for supposing that it contains burnt sugar.

Again, when shining black particles are perceptible in the coffee, and these slowly dissolve in water, giving rise to a dark-coloured solution, it undoubtedly contains the substance in question. Sometimes, when the particles are too small to be discerned by the naked eye, they may be seen under the microscope, and their solution in water watched.

Again, the presence of burnt sugar may be detected by adopting the following process:—From a weighed quantity of dried coffee an infusion in cold water is to be prepared; this must be evaporated in a water-bath, dried, and tasted. If the extract be dark-coloured, brittle, and possess the bitter taste of burnt sugar, no doubt remains as to the presence of that substance.

We are unacquainted with any process by which the quantity of burnt sugar present can be accurately determined, seeing that the extract furnished by pure coffee varies very greatly, and that of adulterated coffee to a still more considerable extent; while also the composition of the burnt sugar is so much changed, that its exact amount cannot be determined in the same manner as grape sugar, but this method gives, at least approximately, the quantity of burnt sugar present.

On the detection of Venetian red.—Sometimes when the Venetian red has been carelessly incorporated with the coffee, particles of it may be detected with the naked eye; but it is not often that it can be discovered in this way. The process to be adopted in ordinary cases is as follows:—A portion of the suspected coffee is to be incinerated, and the colour of the ash noted; if this be deeply coloured and of a rusty red or yellowish hue, then Venetian red, reddle, or some analogous earthy substance has been mixed with the coffee.

If it be desired to ascertain the exact amount of iron present, a weighed quantity of the article should be incinerated, the ash boiled with strong hydrochloric acid, and in the solution the iron estimated by one or the other of the methods given under 'Tea.'

On the estimation of silica.—Silica may occur in one or both of two forms—namely, as chemically bound silica, entering into the composition of the vegetable substance or substances forming the article, and, secondly, as extraneous silica or sand. They may be thus discriminated and estimated separately; a weighed quantity of the article, say three grammes, are incinerated in a platinum capsule, the ash is boiled with concentrated hydrochloric acid, and evaporated to dryness on the water-bath. The dried residue is moistened with hydrochloric acid and treated with boiling water; the silica only in its two forms will remain undissolved. It is separated by filtration, incinerated, and weighed. Thus the total amount of silica is ascertained. It is then boiled for some time with a strong solution of carbonate of soda, which only dissolves the chemically bound silica, or that part which had entered into the composition of the ash. The sand remains undissolved, is collected on a filter, washed with boiling water, incinerated, and weighed. The loss of weight gives the proportion of chemically combined silica.

CHAPTER VI.

CHICORY AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any added foreign vegetable or mineral substance.

CHICORY, succory, or wild endive, *Cychorium Intybus*, belongs to the same natural family of plants as the dandelion, namely, *Compositæ.* It is indigenous, and may be seen growing in various parts of the country, by the road or hedge-side; it may be recognised by the compound character of its flowers, and their bright and beautiful blue colour. It blossoms in the months of August and September. In its natural state the stem rises from one to three feet high, but when cultivated it shoots to the height of five or six feet. The root runs deep into the ground, and is white and fleshy, and yields a milky juice. It is cultivated to some extent in this country as an herbage plant, its excellence in this respect having been strongly insisted upon by the late Arthur Young.

In Germany, and in some parts of the Netherlands and in France, it is extensively cultivated for the sake of its root, which is used as a substitute for coffee. The root is taken up just before the plant blossoms, and when roasted, lard or sometimes butter is added in the proportion of 2 lbs. of lard to 1 cwt. of the kiln-dried root. When ground and exposed to the air, chicory absorbs water readily, and becomes moist and clammy. When prepared on a large scale, the roots are partially dried and sold to the manufacturers of the article, who wash them, cut them in pieces, kiln-dry them, and grind them between fluted rollers into a powder.

The powder of the roasted roots bears striking resemblance to ground coffee, and is still extensively used in Prussia, and other parts of Germany; but as it wants the essential oil, and the rich aromatic flavour of coffee, the caffeine and the caffeo-tannic acid, it has little in common with the latter, except its colour, and has nothing to recommend it beyond its cheapness.

Notwithstanding that chicory 'has nothing to recommend it except its cheapness,' and that it is used exclusively to adulterate coffee, it has of late years been raised in great quantity in this country, in the counties of Surrey, Bedford, and York.

Foreign chicory is considered to be greatly superior to that of English growth, and is consequently much dearer.

COMPOSITION OF CHICORY.

Chicory root has been subjected to examination and analysis by Dr. Letheby at the author's request, and the following is his report on the results obtained, namely,—

‘1st. In its recent, or raw state.

‘2nd. In the kiln-dried condition.

‘3rd. In the roasted and powdered form, as it is used for the adulteration of coffee.

‘The *raw root* furnishes a milky juice, which owes its opacity to the presence of an inert vegetable substance named *Inuline*. The juice is very bitter, and, when filtered and heated, it shows, by its turbidity, that it contains a small quantity of albumen.

‘When macerated in cold water, it yields about 13 per cent. of solid matter or extractive, which gives to the solution a very bitter taste. By Fehling's test, it was found that the raw root contained 1·1 per cent. of grape-sugar or glucose.

‘The *kiln-dried root* possesses all the characters of the preceding, but in a higher degree, for water extracts about 50 per cent. of solid matter; and the solution furnished to Fehling's test as much as 10·5 per cent. of sugar.

‘Neither of these specimens exhibited the least trace of starch, but by boiling in water, filtering, and cooling, they yielded a small quantity of a white powder, which has all the characters of Inuline.

‘The absence of starch in the state in which the root is ordinarily used is also conclusively shown by means of the microscope; and we find that the tissue contains abundance of cellulose, which, by the action of strong sulphuric acid, gives a product that renders iodine blue.

‘The *roasted chicory root* yields from 45 to 65 per cent. of soluble extractive. Its solution in water is acid, and it does not possess the peculiar bitter taste of the raw root; but the taste of the liquid is more like that of burnt sugar. The copper test shows the presence of from 10 to 13 per cent. of sugar.

‘The following analyses represent the percentage composition of the root in its different conditions:—

	Raw Root.	Kiln-dried.
Hygroscopic moisture . . .	77·0	15·0
Gummy matter (like pectine) .	7·5	20·8
Glucose, or grape sugar . .	1·1	10·5
Bitter extractive	4·0	19·3
Fatty matter	0·6	1·9
Cellulose, inuline, & woody matter	9·0	29·5
Ash	0·8	3·0
	100·0	100·0

‘The composition of the *roasted root* was as follows:—

	1st Specimen.	2nd Specimen.
Hygroscopic moisture	14·5	12·8
Gummy matter	9·5	14·9
Glucose	12·2	10·4
Matter like burnt sugar	29·1	24·4
Fatty matter	2·0	2·2
Brown or burnt woody matter	28·4	28·5
Ash	4·3	6·8
	100·0	100·0

Messrs. Graham, Stenhouse, and Campbell[1] found in four samples of chicory the following percentages of grape-sugar :—

	Raw.	Roasted.
Foreign chicory	23·76	11·98
Guernsey "	30·49	15·96
English "	35·23	17·98
Yorkshire "	32·06	9·86

It is evident from these analyses, that the quantity of sugar found by Dr. Letheby in the raw root was much less than that usually present.

The quantities of sugar in mangold-wurzel, carrots, turnips, parsnips, beet, and dandelion roots were found to be nearly as great as in chicory, and hence the sugar present in it does not afford a means by which it may be distinguished from other sweet roots when mixed with coffee (p. 164).

By an examination of the analyses above given, it will be seen that the root does not contain anything which can possibly be regarded as a substitute for coffee. It will be also manifest that in the process of roasting the bitter principle of the recent root is partly destroyed, and that by the torrefaction of the saccharine and other constituents a quantity of caramel is produced which has no virtue beyond that of burnt sugar.

The chief constituents of chicory, therefore, are the *gum*, *glucose*—converted into caramel by roasting—*inuline*, *cellulose*, and various *mineral salts*. The *oil*, sometimes amounting to nearly 5 per cent., is derived for the most part from the lard used in the roasting. The *nitrogen* in chicory is less than that found in coffee, owing to the absence of the alkaloid found in the latter. The nitrogen varies in chicory from 1·42 to 1·86 per cent.

The *ash* of the samples analysed by Dr. Letheby had the following composition :—

	1st Specimen.	2nd Specimen.
Chloride of potassium	0·22	0·45
Sulphate of potash	0·97	0·98
Phosphate of potash	1·41	1·37
" of magnesia	0·30	0·53
" of lime	0·40	0·81
Carbonate of lime	0·10	0·26
Alumina and oxide of iron	0·20	0·20
Sand	0·70	2·20
	4·30	6·80

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[1] Chemical Report on the mode of detecting vegetable substances mixed with coffee, Dec. 1852.

Mr. Allen gives the average ash of chicory at about 5 per cent., of which two-fifths only are soluble in water, whereas three-fourths of coffee ash are dissolved by that menstruum.

The following represents the percentage composition of the ash of four samples of chicory, according to Messrs. Graham and Stenhouse:—

	Darkest English Yorkshire.	English.	Foreign.	Guernsey.
Potash	33·48	24·88	29·56	32·07
Soda	8·12	15·10	2·04	3·81
Lime	9·38	9·60	5·00	5·31
Magnesia	5·27	7·22	3·42	3·85
Sesquioxide of iron	3·81	3·13	5·32	3·52
Sulphuric acid	10·29	10·53	5·38	6·01
Chlorine	4·93	4·68	3·23	4·56
Carbonic acid	1·78	2·88	2·80	3·19
Phosphoric acid	10·66	11·27	7·06	6·65
Silica	3·81	2·61	12·75	10·52
Sand	9·32	8·08	23·10	20·19
	100·85	99·98	100·66	99·68

Messrs. Graham and Stenhouse found the silica and sand insoluble in acids to be, in four samples of roasted chicory, as follows:—10·69, 13·13, 30·71, and 35·85 per cent. of the ash; the quantities of this silica soluble in alkali, representing the chemically combined chicory silica, was, in the same samples, 8·08, 9·32, 20·19, and 23·10 parts. The silica insoluble in the alkali was, of course, derived from the sand and dirt adhering to the imperfectly cleansed roots.

It thus appears that the chief characteristics of the ash of chicory, as contrasted with the ash of coffee, are the presence of notable quantities of soda and chlorine, and the large amount of sesquioxide of iron and silica.

STRUCTURE OF CHICORY ROOT.

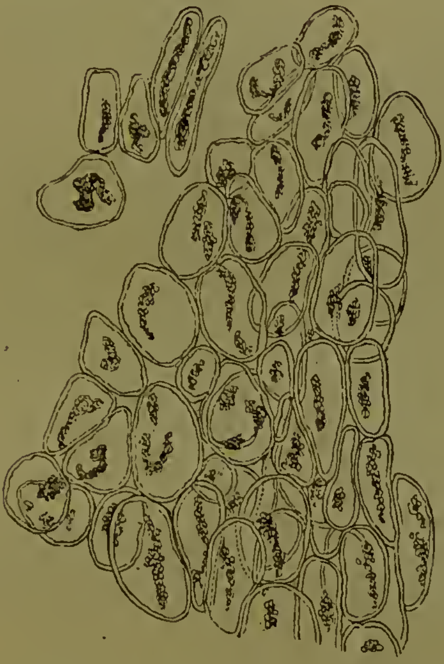
In the raw chicory root four parts or structures may be distinguished with facility: *cells, dotted vessels, vessels of the latex*, and *woody fibre*.

When the adulterating grinder or merchant, in the secresy of his own warehouse, first reduced chicory root, parsnips, corn, beans, &c., to charred and nearly impalpable powders, the idea probably never entered his mind that enough of the distinctive structural characters of each of these substances still remained undestroyed, to enable the man of science to drag to light his guilty deeds, and to detect their presence in every parcel of adulterated coffee sent out from his premises.

In the roasted and charred chicory root the same structures may be detected as are distinguishable in the raw or unroasted root.

The chief part of the root is made up of little utricles or *cells*. These are generally of a rounded form, but sometimes they are narrow and elongated. The former occur where the pressure is least and the root soft; the latter in the neighbourhood of the vessels (fig. 43).

Fig. 43.



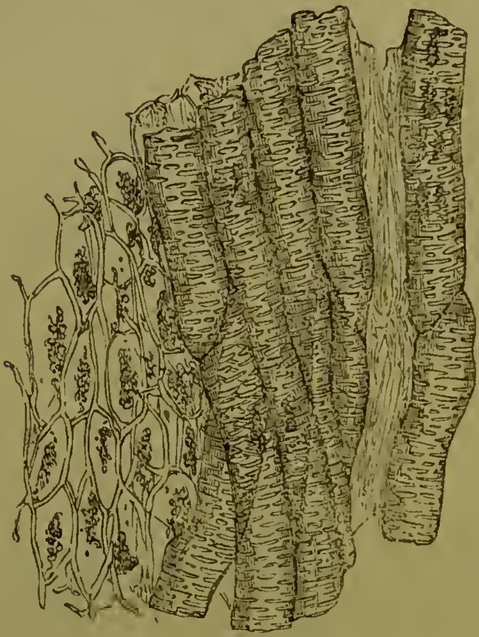
Fragment of ROASTED CHICORY ROOT, taken from a sample of adulterated coffee, showing the cells of which it is principally constituted. Drawn with the Camera Lucida, and magnified 140 diameters.

The *dotted vessels* are particularly abundant in the central and harder parts of the root, which they traverse in bundles: they are cylindrical unbranched tubes, tapering to a point at either extremity, and elegantly marked on the surface with short fibres, describing an interrupted spiral course (fig. 44).

In studying the structure of chicory root, we have clearly made out the origin of the dotted vessels in narrow elongated cells, tapering to a sharp point at either end, at first smooth, but subsequently exhibiting faint oblique markings.

The vessels of the latex, *vasa lacticentia*, are present in most plants, having a milky juice or sap; they form branched and frequently anastomosing tubes, of smaller diameter than the dotted vessels, and with smooth membranous parietes (fig. 45).

Fig. 44.



Fragment of Roasted Chicory Root, taken from a sample of adulterated coffee, showing the dotted or interrupted spiral vessels, which pass in bundles through the central parts of the root. Drawn with the Camera Lucida, and magnified 140 diameters.

These vessels afford a useful means by which chicory may be distinguished from most other roots employed in the adulteration of coffee.

The *woody* fibre of chicory root does not present any markings or other peculiarities of structure of a distinctive character.

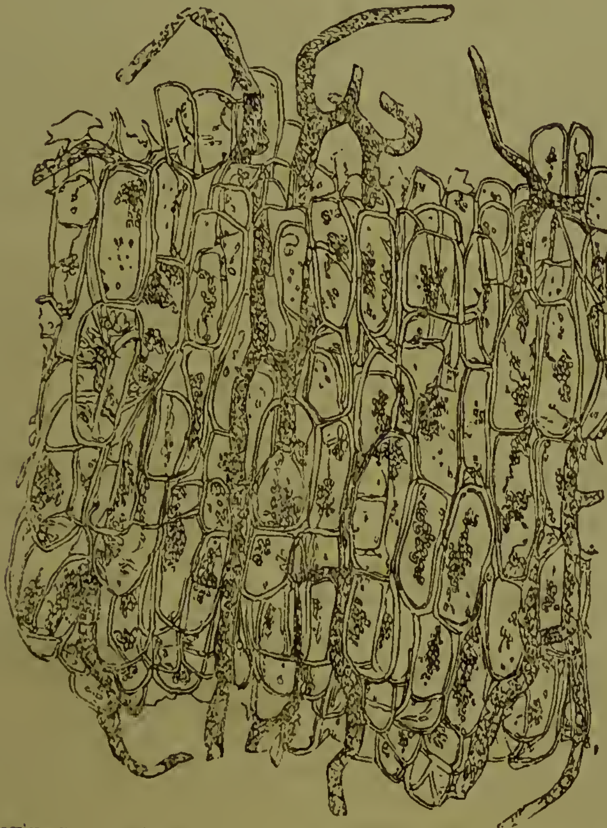
PROPERTIES OF CHICORY.

Recent chicory root is possessed of active medicinal properties, in consequence of which it has long been included in the 'Materia Medica.'

These properties resemble closely those of the allied plant, the dandelion, in reference to which we find, in the work of Dr. Pereira, the following observations:—

'Its obvious effects are those of a stomachic and tonic. In large doses it acts as a mild aperient. Its diuretic operation is less obvious and constant. In various chronic diseases, its continued use is attended with alterative and resolvent effects; but where the digestive organs are weak, and readily disordered, taraxacum is very apt to occasion dyspepsia, flatulency, pain, and diarrhœa.'

Fig. 45.



This engraving represents the narrow and branched vessels (*Vasa lacticentia*), so abundant in CHICORY ROOT, which convey the milky juice of that plant, and also show their relation to the ordinary utricles or cells, of which the substance of the root is principally made up.

These remarks of course apply to the recent root. Professor Johnston, whose views appear to us more favourable than the facts warrant, thus expressed himself in regard to roasted chicory[1]:—

'It possesses in no degree the pleasant aroma which recommends the genuine roasted coffee.

'The active ingredients in roasted chicory are, first, the empyreumatic volatile oil: this is produced during the roasting: and though not so fragrant, this oil probably exercises upon the system some of the gently exciting, nerve-soothing, and hunger-staying influence of the similar ingredients contained in tea and coffee; and, second, the bitter principle. When taken unmixed, this substance is to many, while they are unaccustomed to it, not only disagreeable, but nauseous in a high degree. It may, however, like many other bitter principles, possess, as I have said, a tonic or strengthening property. Taken in moderate quantities these ingredients of chicory are probably not injurious to health, but by prolonged and frequent use they produce heartburn, cramp in the stomach, loss of appetite, acidity in the mouth, constipation with intermittent diarrhœa, weakness of the limbs, tremblings, sleeplessness, a drunken cloudiness of the senses, &c. &c. At the best, therefore, chicory is a substitute for coffee, to which only those to whom the price is an object ought to have recourse.'

---

[1] 'Chemistry of Common Life.'

For ourselves, we would remark that, while chicory is substituted to an enormous extent for coffee, it yet possesses none of the characteristics of a true substitute. We believe that the quantity of 'empyreumatic essential oil' present is infinitesimal, and that the 'bitter principle' consists chiefly of burnt sugar.

Although we are not disposed to attach, therefore, much weight to these so-called *active ingredients* in roasted chicory, it is yet certain that it does contain constituents possessing active and medicinal properties not of a desirable character in an article of food.

Thus, it is very certain that the infusion of roasted chicory is aperient.

In proof of this we will cite the results of some observations of our own.

Three persons partook of chicory at breakfast. The infusion was dark-coloured, thick, destitute of the agreeable and refreshing aroma so characteristic of coffee, and was of a bitter taste.

Each individual experienced, for some time after drinking the infusion, a sensation of heaviness, a feeling of weight at the stomach, and great indisposition to exertion; in two, headache set in; and in the third, the bowels were relaxed.

In second and third trials of the chicory, the same feelings, weight at the stomach, and want of energy, were experienced, but no headache or diarrhœa.

Several other trials were subsequently made, with nearly similar results.

But chicory, it will be said, is seldom taken alone in this country, and when mixed with coffee these effects are not produced.

Two persons partook, for a considerable period, twice a day, of an article denominated coffee, costing one shilling and sixpence a pound, and largely adulterated with chicory: during nearly the whole of this time they both suffered more or less from diarrhœa.

From the result of these trials, therefore, we are warranted in concluding that at least some doubt is attached to the assertion of the 'wholesome' properties of chicory root as an article of diet.

So well are mothers in France and Germany acquainted with the aperient properties of chicory, that they frequently give infants and young children a strong infusion of the roasted root as an aperient, preferring it to ordinary medicine on account of its less disagreeable flavour.

Again, it is the opinion of an eminent oculist in Vienna, Professor Beer, that the continual use of chicory seriously affects the nervous system, and gives rise to blindness from amaurosis.

These are serious effects of the use of chicory, and should make those in authority hesitate before they foster the use of this article by giving to its sale an undue and unfair preference.

The greater part of the chicory used is grown in this country, and does not pay any duty; and yet it is allowed to be mixed to any extent with coffee, an article bearing a high duty.

Of the 'nutritive' properties of chicory, of which Sir Charles Wood entertained so high an opinion, we need say but little, feeling assured that the reader will scarcely be disposed to question the accuracy of the assertion, that a mouthful of good wheaten bread contains more nourishment than a cup of infusion of chicory.

Chicory and coffee, then, may be thus contrasted.

They differ from each other in their botanical nature, in chemical composition, and in physiological action and properties.

Coffee is the fruit or seed of a tree, while chicory is the succulent root of a herbaceous plant. Now it is a well-ascertained fact, that of all parts of vegetables, the fruit and seeds usually possess the most active properties: this is no doubt due to the circumstance of their being freely exposed to the influence of light and air—agencies which promote chemical changes in the plant, and so effect the elaboration of those complex organic substances on which the activity of vegetables depends. On the other hand, it must be manifest, that, as the roots are removed from the influence of these powerful agencies, they cannot be so richly endowed with active properties; and, indeed, there are but few roots which contain either alkaloid or volatile oil—the constituents which give to coffee its peculiar virtues. The distinction, therefore, between the properties of the seeds and roots of plants is very important, and it is especially so in the case before us.

The infusion of the one is heavy, mawkish, and nearly destitute of aroma; that of the other is light, fragrant, and refreshing.

Coffee contains, as already shown, at least three active principles, or constituents, viz., the volatile oil, the tannin, and the alkaloid caffeine; in chicory there are no analogous constituents.

Coffee exerts on the system marked and highly important physiological effects, of a beneficial character. There is no proof that chicory exerts any one of these effects, while it is very questionable whether the properties which it does possess are not really hurtful.

ADULTERATIONS OF CHICORY.

What! chicory adulterated? A substance used to adulterate another article, itself adulterated? Impossible! Improbable as the thing appears, it is nevertheless true.

When it is remembered that all the vegetable substances employed in the adulteration of coffee require to be charred or roasted, and that to effect this a suitable apparatus is required, such as but few retail grocers possess, it at once becomes at least probable that these substances are prepared for them by other parties.

This impression acquires increased force when it becomes known that the majority of grocers buy their chicory, not in nibs, but *in powder*, and that this is supplied to them by certain wholesale chicory houses, which charge for it, in general, a less price than for the nibs, or unground root itself, or than genuine chicory powder can be fairly sold at.

The substances which are either substituted for chicory, or mixed with it, are very numerous; several of these we have ourselves detected, while others have been discovered from time to time by different parties. *They include all those employed in the adulteration of coffee*; indeed the greater number of substances met with in adulterated coffee are introduced into it through the chicory with which it is mixed.

This conclusion is deduced not only from the examination of a considerable number of samples of powdered chicory, but from evidence derived from other sources.

Dr. Pereira, in 1845, published in the 'Pharmaceutical Journal' two very useful articles on the adulteration of coffee and chicory: from the first of these—that on coffee—we extract the following remarks:—

'But while the grocers, on the one hand, cheat their customers by adulterating coffee with chicory, the chicory dealers in turn cheat the grocers by adulterating chicory;' and he then goes on to describe certain adulterations of chicory, as those with *Hambro' powder and coffee-flights.*

Another circumstance which proves not only that chicory is adulterated, but also that the sellers of chicory powder are in some cases parties to the adulteration, is that the powder is sometimes sold under the market price at which genuine chicory can be procured.

The substances with which chicory has been ascertained to be adulterated are, as already stated, all those articles which have been enumerated under coffee; namely, different kinds of roasted corn, as *wheat*, and *rye*, *beans*, *acorns*, *carrots*, *mangold-wurzel*, *beet-root*, *sawdust*, *baked livers*, *burnt sugar* or *black jack*, *Venetian red*, and other analogous red earths.

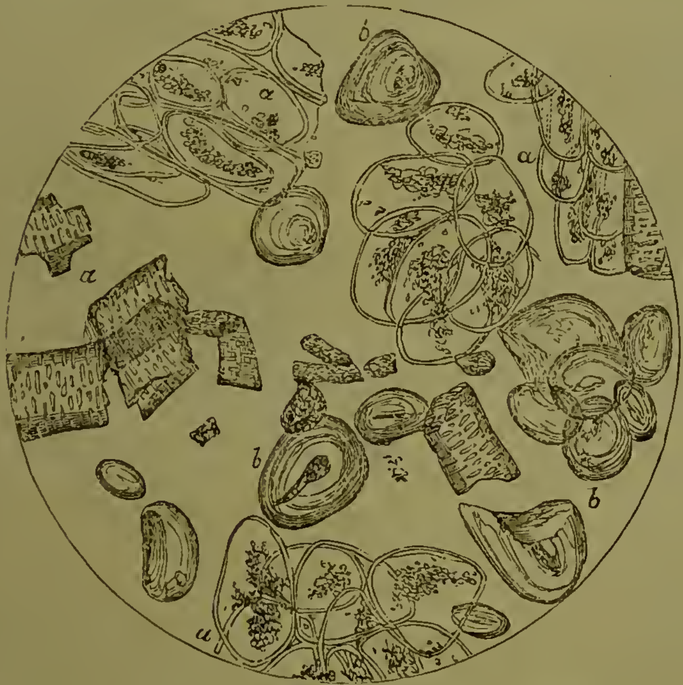
With regard to the use of carrots and parsnips, Mr. Gay, in evidence before the Parliamentary Committee of 1855, under the presidency of the late Mr. Scholefield, made the following statement:—

'I remember, one year when chicory was worth 21*l.* per ton, manufacturing 700 tons of carrots into chicory. They were grown by one gentleman in Surrey, and supplied to the house where I was, and also 350 tons of parsnips.'

Besides the above-named articles, '*coffee-flights*' and '*Hambro' powder*' have been used, as also, it has been alleged, *exhausted tan*, known as *croats*, and *oak-bark powder*.

The following engravings exhibit the microscopical characters of chicory adulterated with wheat flour, also with a substance resembling ground acorn (figs. 46 and 47).

Fig. 46.



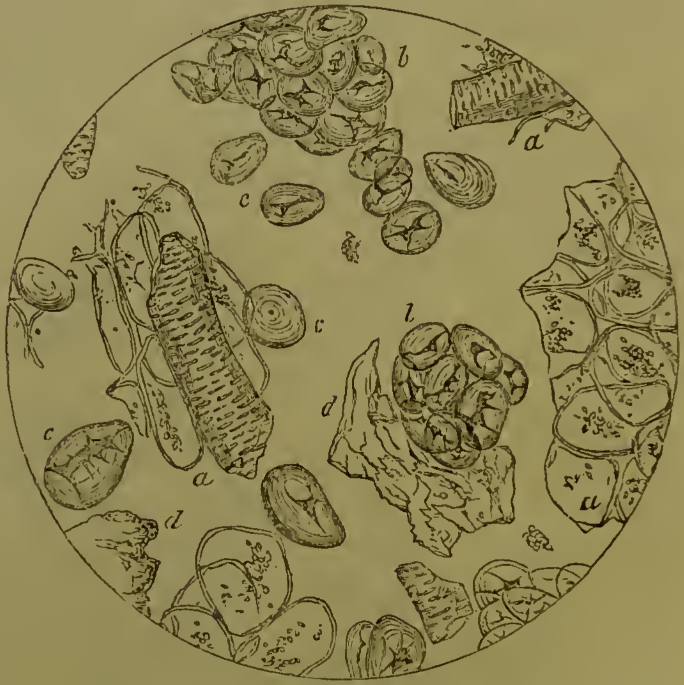
Sample of Chicory, *adulterated with roasted wheat farina.* The structures marked *a a* are the cells and vessels of *chicory root*, while those marked *b b* are the starch corpuscles of *wheat*. No bodies in the least resembling these occur in genuine chicory powder.

According to Dr. Pereira, '*Hambro' powder* consists of roasted and ground peas, &c., coloured with Venetian red. The term *coffee-flights* is applied to the thin membranous coat (endocarp) which separates from the coffee-seed in the act of roasting.'

In Dr. Pereira's article on chicory we meet with the following remarks in reference to Venetian red:—

'In a previous number we explained the nature of *Venetian red.* It is essentially the sesquioxide of iron, obtained by calcining common copperas (sulphate of iron). The different colours of the product depend on the temperature to which the sesquioxide is subjected. When it has been exposed to an intense white heat its colour deepens, and it is then termed *purple-brown.* The lighter tint of Venetian red is produced by adulteration. Our informant (a manufacturer) told us that Venetian red was 'adulterated to suit the various prices of the market.' We did not think it expedient to pry into the nature of the adulterating ingredient, but a friend suggests that it is *reddle,* the substance used for marking sheep.

Fig. 47.



a a, cells of *chicory* ; *b b*, fragments containing numerous starch corpuscles, resembling those of *acorn* ; *c c*, separate starch granules ; *d d*, portions of a brown membrane, without apparent organisation, very commonly observed, and derived from the testæ of the seed.

'Venetian red is, we believe, the principal substance at present used for colouring chicory ; occasionally other agents have been employed. A dealer tells us that he once bought a quantity of chicory which contained 20 per cent. of *logwood* and *mahogany dust.*'

RESULTS OF THE EXAMINATION OF SAMPLES.

The results of the microscopical examination, made some years since, of *thirty-four* samples of chicory powder, some of which were purchased of different grocers and others obtained from manufacturers, were,—

First, That *fourteen* samples were *adulterated.*

Second, That in *nine* the adulteration consisted of *roasted corn.*

Third, That *ground scorched beans* were present in *four* of the samples.

Fourth, That in *one* case ground *acorns* was detected.

The results of the examination of *twenty-three* other samples made at a subsequent period were,—

First, That *eleven or one-half of the samples were adulterated.*

Second, That *four of the chicory powders were adulterated with roasted wheat.*

Third, That *ground acorns were present in an equal number of cases.*

Fourth, That *two of the samples contained sawdust, and one mahogany sawdust.*

Fifth, That *mangold-wurzel was detected in one of the chicories.*

Sixth, That *in one instance roasted carrot was present.*

Lastly, the results of the examination of *thirty-eight* additional samples of chicory, both as purchased from shops and as procured from manufacturers, and which examination was instituted mainly for the purpose of determining whether Venetian red or other analogous ferruginous earth was employed to colour chicory, were,—

First, That out of the *eighteen* samples of chicory procured from manufacturers, *five* were adulterated with *roasted wheat farina.*

Second, That *several* of the samples yielded a *coloured ash*, derived in some cases in part from the soil in which the chicory had been grown, and from which the roots had been but imperfectly freed.

Third, That out of the *sixteen* samples of chicory purchased at the establishments of different grocers in the metropolis, *one* was adulterated with *roasted farina.*

Fourth, That the *ashes* of several of the samples were *highly coloured*, indicating the presence of some *red ferruginous earth*, as *reddle or Venetian red.* In two samples the incorporation was so imperfect that we were enabled to separate large particles of the Venetian red from the chicory powder.

We have now shown,

That chicory, an article used to adulterate another article, is itself largely adulterated;

That the dealers in or manufacturers of chicory are in many cases the parties who practise this adulteration.

We are sorry, however, to declare that in those instances in which the retail grocers do not themselves adulterate the chicory they vend, we are unable to acquit them of guilty knowledge of and participation in the fraud: this knowledge is displayed in the fact that the grocer frequently purchases chicory in powder at a price at which it is not possible to procure genuine chicory.

The prices demanded for the several samples analysed varied from 5*d.* to 1*s.* per lb.; the ordinary charge being 8*d.* The price of chicory in powder to the trade ranged in general from 20*s.* to 32*s.* per cwt.; thus the profit of the retail grocer on the sale of chicory powder was seldom under cent. per cent., and often much above it.

On the detection of the adulterations of chicory.—The Chancellor of the Exchequer, in May 1850, stated in the House of Commons, that 'having desired the Board of Inland Revenue to state whether there was any ready and available proof of the mixture of chicory with coffee, he had received a reply to the effect, that four experienced persons having been employed in making experiments, the result of the inquiry was, that neither by chemical tests, nor in any other way, could they ascertain with any degree of certainty whether the mixture contained chicory or not.' On being reminded of this Report by Mr. Scholefield, Mr. George Phillips made this notable reply:—'Yes, that is as far back as 1849. The fact is, the subject had not then been studied as regards the adulteration of coffee and chicory.'

So that at that time, on the admission thus publicly avowed by the chief scientific authority then connected with the Excise, the grocers, for anything the Excise could do, might adulterate their coffee and chicory as much as they pleased! Pretty protection of the revenue truly!

Notwithstanding this formal and apparently authoritative statement, the fact is that few things are easier of detection than the presence of chicory in coffee by means of the microscope: the detection of the adulterations of chicory itself are for the most part not more difficult.

The identification of chicory with certainty, either in the pure state, or when mixed with other articles, by other means than the microscope, is by no means easy, if it be not impossible, in the present state of science.

It has been repeatedly stated that coffee and chicory may be distinguished by the manner in which they comport themselves when placed on the surface of water; the chicory powder, it is said, soon sinks, while coffee floats. In the case of the majority of samples of chicory examined this test completely failed, as the powder did not sink, but rested on the surface for a considerable time, and continued perfectly dry—a result possibly attributable to the presence of the lard used in the roasting of the nibs.

Another way recommended to detect an admixture of chicory with coffee, is to add some of the suspected powder to cold water. If chicory be present, the water will quickly become coloured, and by the depth of the colour the proportion of chicory may be guessed at. This method is, however, utterly fallacious, since the colour may arise from the presence of burnt sugar, so commonly used, or of roasted wheat, carrot, and other similar substances.

The adulteration with chicory has been attempted to be established by the relative specific gravities of infusions made from equal quantities of coffee and chicory. It has been found that infusion of coffee is of much lower specific gravity than one of chicory, the difference in fact being about 1 to 3; but since other sweet roots, as well as maize, rye, &c., yield infusions equally heavy with that of chicory, the test is useless as a means of determining the fact of the adulteration of coffee with chicory. The colour of the infusion and its specific gravity, doubtless afford rough and general indications as to whether any particular samples of coffee are genuine or not, but it is impossible by these characters to pronounce an opinion as to the precise nature of the adulteration practised.

The difficulty of detecting chicory by chemical means arises from the absence of any peculiar and distinctive principles in the roasted root. Various attempts have been made with the view to discover some characteristic reactions and peculiarities of composition; Messrs. Graham, Stenhouse, and Campbell especially have directed their attention to this subject.

These chemists have, among other points, endeavoured to make use of *the colour* and *specific gravity* of the different infusions used as a means of detecting the adulterations of coffee with chicory and other roots; but these data are not capable of affording any specific information, although they are sufficient in many cases to establish the general fact of adulteration. (Table, p. 164.)

They have also endeavoured to avail themselves of the presence of *glucose* or *grape-sugar* in chicory as a means of discrimination; thus, while the sugar in roasted coffee rarely exceeds 1 per cent., and is usually only half this quantity, in roasted chicory it has been found to range from 9·86 to 17·98 per cent.; but since other sweet roots, as beet-root, mangold-wurzel, turnips, dandelion, carrots, and parsnips, contain on the average as much sugar as chicory, this means utterly fails as a test for chicory. The utmost that can justly be inferred from the presence of a considerable amount of sugar in ground coffee is, that it is adulterated, and *probably* with one or other of the roots above-named. (Table, p. 164.) Further, the presence of sugar in small quantity only affords no proof of the genuineness of coffee, since some of the cereals and other substances employed to adulterate coffee are equally deficient with it in saccharine matter. Lastly, sugar is often purposely added to coffee, sometimes during the roasting, and subsequently in the form of burnt sugar or black jack.

Again, they have availed themselves of the quantity of *silica* present in the ashes of coffee and other vegetable adulterants as another means of discrimination. The silica of roasted coffee averages usually about a quarter and rarely approaches one half per cent.; while, as has been already shown, the sand and silica, insoluble in acids, of four samples of roasted chicory amounted to as much as 10·69, 13·13, 30·71, and 35·85 per cent. of the ash: but in roasted dandelion root the proportion of silica is as great as in chicory, great part of the silica in both cases being derived from the dirt still adhering to the imperfectly cleansed roots. The same is the case with the roots of carrots and parsnips prepared in the same rough way for use as chicory root. The presence, therefore, of a large excess of silica does not prove the fact of adulteration with chicory; indeed, it can scarcely be said to afford decisive proof of adulteration of any kind. In the cereals again, with the exception of maize, the ash of which contains about 2 per cent., the silica is high, as shown by the researches of Messrs. Ogston and Way, who state that in wheat the silica varies from 20·5 to 54·6 per cent.; in barley from 23·6 to 70·77; in oats from 38·48 to 50·03; while in rye it is about 9·22; but it must be remembered that nearly the whole of the silica found in the cereals is present in them in the combined state, and therefore must not be confounded with that accidentally present in the roots of most plants.

Lastly, Messrs. Graham and Stenhouse have examined the *ash* of coffee and chicory, and certain other adulterants, with a view to discover distinctive characters. The principal differences in the composition of the ash are shown by the figures given below:—

	In Coffee Ash.	In Chicory Ash.
Silica and sand . . .	—	10·69 to 35·85
Carbonic acid . . .	14·92	1·78 to 3·19
Sesquioxide of iron . .	0·44 to 0·98	3·13 to 5·32
Chlorine	0·26 to 1·11	3·28 to 4·93

Extending the comparison further, however, we find in a variety of other vegetable substances, even of those used in the adulteration of chicory and coffee, an excess of all the constituents referred to above over the quantities usually contained in coffee. Some of the substances in which excess of *silica* occurs have already been mentioned. *Carbonic acid* occurs in nearly the same proportion in acorns, parsnip, beet-root, carrot, and turnip, as in coffee; the quantity of chlorine approximates to chicory in acorns, parsnip, carrot, turnip, and dandelion roots; lastly, the *iron* is excessive in dandelion and beet-root, and would be so no doubt in carrot and parsnip roots imperfectly cleansed and freed from dirt. Besides, all conclusions based upon an excess of iron, except the general one that adulteration with some substance containing an excess of that metal has been practised, are precluded by the fact that chicory and other roots employed to sophisticate coffee are themselves often adulterated with red ferruginous earths, as Venetian red and reddle, which themselves frequently contain an admixture of carbonic acid, lime, and silica.

The ash of coffee adulterated with any of the cereals, and also to a less extent with lupins, peas, and beans, is, of course, distinguished by the large amount of phosphoric acid present. In coffee the phosphoric acid may be set down at about 10 per cent. of the ash; in chicory it varies from 6·85 to 11·27; in lupins it is usually about 25 per cent., and in maize 44 per cent.

With regard to the *nitrogen* of coffee and chicory, the authors of the Report under consideration remark:—'The proportion of nitrogen in coffee is, therefore, greater than in chicory; but the difference is not sufficiently marked to distinguish the two substances readily from each other. The conclusion may, however, be drawn that less than 2 per per cent. of nitrogen in coffee is a strong presumption of adulteration.'

DETECTION OF THE ADULTERATIONS OF CHICORY.

By the microscope.—It is obviously best, therefore, not *to waste time* in the prosecution of chemical methods of research leading to no certain results, but at once to have recourse to the microscope; by this instrument all the adulterations of coffee and chicory with vegetable substances are discoverable with ease and certainty. In the case of chicory, it is only necessary to ascertain whether those structures characteristic of its root (figs. 44, 45, and 46) are present or not, to observe well the size of the cells, whether they contain starch or not, the size and character of the vessels, and especially whether *vasa lacticentia* are present.

For this purpose, a grain or so of the powder should be placed on a slip of glass, a drop or two of water added, and the larger particles, which swell up and become more visible than when in the dry state, torn into pieces by means of needles. A little of the powder should then be placed on a clean slide, covered with a piece of thin glass, and subjected to examination with a ½- or ¼-inch object-glass.

The adulterations of chicory being for the most part the same as those of coffee, similar means must be had recourse to for their detection: when these consist of vegetable substances of any kind, the microscope will be found to supply the only ready and certain means of detection; when of chemical substances, as burnt sugar or Venetian red, chemical methods of research must be resorted to. For a detailed description of the characters of the various substances used in the adulteration of coffee and chicory, and of the means for their discovery, the reader is referred to the preceding article on 'Coffee.'

Detection and estimation of starch.—The detection of substances containing starch by *chemical means* is attended with even greater difficulties than in the case of coffee, the blue colour developed on the addition of iodine being obscured by the deep brown colour of the infusion of chicory.

Starch may be thus detected, however: iodine may be applied to a small quantity of the article placed under the microscope, when the blue coloration which ensues will be immediately recognised; but in order to determine the quantity of starch present we must proceed as follows:

—A carefully prepared infusion of the article is to be made: this is to be divided into two parts; in one, the sugar is to be determined by Fehling's solution, or by converting it into alcohol by fermentation; the other is to be boiled with dilute sulphuric acid until all the starch is changed into grape-sugar, from the amount of which present (deducting, of course, the glucose not derived from the conversion of the starch) the starch itself may be calculated. The methods for the estimation of sugar will be found fully described in the article on 'Sugar.'

Detection and estimation of Venetian red and reddle.—The evidence of the use of *reddle and Venetian red* is principally derived from the incineration of a certain quantity of the suspected chicory powder, and by analysis of the ash. All vegetable substances, whether coloured or not, yield, on incineration, a greyish-white ash. The ash of coloured earthy substances, on the contrary, after being burned in a crucible, remains more or less coloured.

As, however, chicory is the root of a plant, and as the earthy matter is but seldom entirely removed from it by washing, the ash of even genuine chicory not unfrequently exhibits, on this account, a slight degree of coloration, being occasionally brownish, or of light-fawn colour. It is only, therefore, when the ash is decidedly coloured, and especially when of a red or rusty-red colour, that the presence of Venetian red, reddle, or some other analogous substance, can be inferred with certainty.

In these facts, therefore, we have a ready means of determining whether a sample of chicory, or any other vegetable powder, contains an admixture of any ferruginous colouring matter, a conclusion which may be confirmed by chemical analysis.

Although the presence of iron is sufficiently indicated by the colour of the ash of chicory, and most other vegetable substances, yet in some cases it becomes necessary to determine its amount. For a ready method of effecting this object see the article on 'Tea.'

The cases, then, of coffee and chicory afford striking illustrations of what can be effected in the discovery of adulteration by means of the microscope.

This article on 'Chicory' may be concluded by a reference to the alteration which has of late years taken place in the law, whereby it is required that chicory should not be sold mixed with coffee, except the fact of such admixture is specified by a label. This law is, however, constantly evaded. The mixture is sometimes sold without the label, in other cases it is palmed off where coffee only is asked for; the words of the label are often hid in the folds of the wrapper; and, lastly, in some instances the so-called mixture consists almost entirely of chicory.

CHAPTER VII.

COCOA AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any foreign animal, vegetable, or mineral substance, or more than 2 per cent. of the husk of cocoa. The abstraction of a portion of the fat not to be deemed an adulteration; all mixtures of sugar, flour, and arrow-roots, or starch, to be named and labelled as mixtures. The above definition to apply to all chocolates, chocolate being merely another name for cocoa.

Cocoa is prepared from the seeds of *Theobroma Cacao*, so named by Linnæus from the Greek word θεός, God, and βρῶμα, food, signifying that cocoa is a food fit for the gods. It belongs to the natural order *Byttneriaceæ* or *Sterculiaceæ*.

It is a small but handsome tree, indigenous to the West Indies and Central America. 'It grows spontaneously in Mexico and on the coast of Caraccas, and forms whole forests in Demerara. It is cultivated also in the Mauritius and in the French island of Bourbon.'—*Johnston.*

The seeds or beans are enclosed in a pod or fruit somewhat like that of a cucumber, being usually about five inches long, and three-and-a-half in diameter. Each fruit contains in general from twenty to thirty beans, disposed in five rows, which are divided from each other by partitions. Occupying the divisions of the fruit and surrounding the seeds is a rose-coloured spongy substance, resembling that of water-melons.

The above description applies to fruits of average size; sometimes the fruits are so large, especially those grown in Central America, that they contain as many as from forty to fifty seeds; while others, as those grown in the West Indian Islands, Berbice, and Demerara, are much smaller, and enclose only from six to fifteen seeds.

During maturation the fruits change from green to dark yellow; they are then plucked, opened, the seeds cleared of the spongy substance, and spread out to dry in the air.

In the West Indies, immediately that they are dried, the beans are packed up and are ready for the market; but in the Caraccas they are subjected to slight fermentation; for this purpose they are either put into chests or tubs, which are covered over with boards, the beans being turned over every morning to equalise the fermentation, or else they are put into pits or trenches dug in the earth. Lastly, they are exposed to the sun and dried.

During the process the beans emit a good deal of moisture, lose weight, as well as part of their bitterness and acrimony.

The seeds which have undergone the process of fermentation are considered the best; they are larger, of a darker brown colour, and after roasting, throw off their husks readily, and split easily into several pieces or lobes. They have an agreeable mildly bitter taste, without acrimony.

The beans of Guiana and West India cocoas, while they are smaller, flatter, smoother, and of a lighter colour, are also more sharp and bitter to the taste. 'They answer best for the extraction of the butter of cacao, but afford a less aromatic and agreeable chocolate.'—*Ure.*

Johnston states that the bitterness and acrimony of taste is greater in the beans of the mainland than in those of the American Islands. The cocoa of Central America is however of superior quality, or at least is more generally esteemed in the European markets than that which is grown in the West Indies. It still retains a greater degree of bitterness, and this may be one reason for the preference given to it.

The cocoa of Trinidad is the variety chiefly consumed in this country.

Previous to being used, the beans are roasted in an apparatus similar to that of a coffee-roaster. When the aroma is well developed the roasting is known to be finished. The beans are turned out, cooled, and freed from their outer husks by fanning and sifting, the inner shell-like husk remaining unbroken. By the roasting, part of the starch is converted into dextrin, and a little of the fat into fatty acids.

Cocoa has been in use in Mexico from time immemorial. It was introduced into Europe by the Spaniards in 1520, and by them it was long kept a secret from the rest of the world.

COMPOSITION OF COCOA.

The following is the composition, according to Lampedius, of 100 parts of the seeds of West Indian cocoa deprived of husk:—

Fatty matter	53·10
Albuminous brown matter, containing the aroma of the bean	16·70
Starch	10·91
Gum	7·75
Lignine	0·90
Red pigment	2·01
Water	5·20
Loss	3·43
	100·00 parts

This analysis, which, however, so far as it goes, is one of the best which has been made, entirely overlooks some of the more important constituents of cocoa, as *the volatile aromatic oil*, the *theobromine*, analogous to the theine of tea, and the *bitter and astringent principle.* The proportion of *starch* appears also to be somewhat underrated.

Payen's and Mitscherlich's analysis corresponds in the main with the above, the analysis of the former chemist being as follows:—

Fatty matter	52
Albuminoid matter	20
Starch	10
Cellulose	2
Water	10
Theobromine	2
Mineral matter	4
	100

Tuchen's analyses, which probably apply to the unshelled beans, are obviously incorrect in several particulars, and need not be quoted.

Two samples of commercial cocoa, the one in cake, the other flaked, analysed by ourselves, furnished the following results:—

	Caked Cocoa.	Flaked Cocoa.
Water	3·77	3·60
Fatty matter	50·20	54·90
Albuminoid matter	16·64	16·51
Starch, gum, cellulose, and colouring matter	25·47	21·27
Theobromine	0·70	0·47
Mineral matter	3·22	3·25
	100·00	100·00

Cocoa, then, contains a great variety of important nutritive principles; as, in addition to the volatile oil, cocoa red, the theobromine, and the bitter principle, gum, starch, much fat and gluten: like milk, it contains every ingredient necessary to the growth and sustenance of the body.

The *volatile oil* is developed during the process of roasting: it is to it that the aroma is due, and which is so powerful when the cocoa is first roasted. Its action on the system is probably similar to the corresponding oils of tea and coffee, although the quantity of this oil in cocoa is much smaller.

Theobromine, like theine, is a white crystallisable substance, but differs from it in containing a much larger proportion of nitrogen, its formula being $C_7H_8N_4O_2$, which is equal to 31·11 per cent. of nitrogen. The proportion of theobromine is said to be about the same as the theine in tea—namely, 2 per cent.

This, however, we believe to be an error, for two reasons; first, because half the article consists of fat; and second, the chief analyst who has met with two per cent. of theobromine is Payen. In Tuchen's analysis the quantities range from 0·38 to 0·66; in Mitscherlich's from

1·2 to 1·5, and in our own analyses from 0·47 to 0·78. Theobromine exists also in smaller quantity in the husk of the bean.

The *bitter and astringent principles* are probably distinct: the bitterness is greater than that of coffee, but the astringency less than that of either tea or coffee.

The *concrete fat or oil* is the predominant ingredient in cocoa, forming over one-half the weight. In its presence cocoa differs remarkably from tea and coffee.

This fatty oil, termed butter of cocoa, is of the consistence of tallow, and has the same fusing point as butter. It is white, of a mild and agreeable flavour, and is not apt to turn rancid. It is soluble in boiling alcohol, from which it is precipitated as the spirit becomes cold. To obtain it in quantity, the beans, after having been steamed and soaked in boiling water for some time, are subjected to strong pressure in canvas bags. The proportion of butter procured by this method is from five to six ounces to a pound of cocoa, some of the oil remaining behind in the beans. It possesses a reddish tinge when first expressed, but becomes white by boiling with water.

It is much used in France for making soap, candles, and pomatum.

The quantity of cocoa butter is so great that in some cases the cocoa is found to be too rich for persons of delicate digestion, and by some makers part therefore of the oil is abstracted with a view to render the cocoa less rich and more digestible. We do not see any objection to this practice, provided the abstraction is acknowledged. The fat thus removed possesses but small commercial value, and hence there is no inducement to remove it on account of its value, and the cocoa that remains after the abstraction is, of course, of a higher money value, and contains in larger proportion all the other important constituents of the seed—namely, the volatile oil, theobromine, bitter and astringent principle, gluten, gum, &c.

Cocoa likewise differs remarkably from tea and coffee in containing a considerable amount of *starch*, an important constituent in nearly all the more valuable vegetable articles of food.

Cocoa red forms the colouring matter of the beans. It is obtained from the aqueous or alcoholic decoction by precipitation with acetate of lead and decomposition of the precipitate after washing with sulphuretted hydrogen. The solution thus prepared possesses a bitter taste, and, according to Watts, 'yields lilac or greyish precipitates with acetate of lead and protochloride of tin; dark green or brown green with ferric salts; and green of various shades, or sometimes violet, with ferrous salts. The colour of the precipitate varies in each case according as the cocoa red in the solution is more or less mixed with other substances.'

The solution absorbs oxygen, becomes acid, the colouring matter being converted into a kind of tannic acid, which is precipitable by gelatine; the cocoa red in its unaltered state is not thus thrown down.

The *shells* or *husks*, according to some authorities, form about 12 per cent. of the weight of the seed, but according to others as much as from 20 to 25 per cent. The latter estimate is far too high, as shown in the following table. The samples from which the following results were obtained were very kindly furnished us by Messrs. Fry and Son.

	Percentage of husk.
Fine Caracas cocoa	13·2
San Antonio, Trinidad	15·1
Fine clayed Bahia	12·0
Finest Trinidad	15·0
Grenada cocoa	11·9
Trinidad „	13·4
Average	13·4

They contain a little theobromine, a very small quantity of fat, mucilage, but no starch, and much vegetable tissue or lignin. They yield to boiling water about half their weight of soluble matter.

The following figures will serve to show the amount of mineral matter contained in the husk and beans of different kinds of cocoa:—

	HUSK.			BEAN.		
	Soluble Ash.	Insoluble Ash.	Total.	Soluble Ash.	Insoluble Ash.	Total.
Fine Caracas cocoa	2·10	18·78	20·88	1·25	2·27	3·52
San Antonio, Trinidad	4·60	13·65	18·25	1·25	1·73	2 98
Fine clayed Bahia	2·04	11·41	13·45	0·90	1·73	2·63
Finest Trinidad	3·64	7·79	11·43	1·00	1·93	2·93
Grenada cocoa	5·01	3·10	8·11	0·81	1·90	2·71
Trinidad „	4·17	7·79	11·96	1·11	1·70	2·81
Average	3·59	10·42	14·01	1·05	1·87	2·93

It will thus be seen that the weight of the ash of the husk and bean of cocoa varies very considerably, the highest amount being for the husk 20·88, and the lowest 8·11, the average being 14·01; and for the bean 2·63 and 3·52 respectively, the average being 2·93. The soluble ash of the husk varies from 2·04 to 5·01, the average being 3·59, and of the bean, which represents of course genuine cocoa, from 0·81 to 1·25, the average being 1·05. Now, it has been proposed by Mr. Wanklyn to calculate from the weight of the soluble part of the ash the proportions of sugar, starch, and cocoa present in any sample of mixed cocoa, taking 2·16 per cent. as the average weight of the soluble ash obtained by extraction from cocoa nibs with water. But since the actual weight of the soluble ash varies so greatly, it seems highly probable that the ash extracted by cold water will vary in like manner; but we have deemed it worth while to put the method, since it has been advanced with considerable pretensions, to a more rigorous examination. Thus—A sample of Caracas cocoa treated with water exactly as directed by Wanklyn, yielded 12·04 per cent. of soluble matters, containing 2·88 per cent. of mineral matter. A sample of Trinidad cocoa, on the contrary, yielded only 6·52 per cent. of soluble matters, including 1·52 per cent. of ash.

It will be observed that neither of these figures corresponds at all to the factor employed by Mr. Wanklyn, namely, 2·16. Had we employed our highest figure, the adulteration would have been but little more than half the amount had we based the calculation upon the lower number. The worthlessness of the method is thus therefore completely established.

The subjoined analyses give the composition of the *ash* of the cocoa bean:—

	Letellier.	Zedeler.
Potash	33·4	37·14
Soda	—	1·23
Lime	11·0	2·9
Magnesia	17·0	16·0
Sulphuric acid	4·5	1·5
Carbonic "	1·0	1·2
Phosphoric "	29·6	39·6
Phosphate of iron	—	0·7
Chlorine	0·2	1·7
Silica	3·3	—
	100·0	102·3

It is obvious, from an examination of the above analyses, that the ash of cocoa is to a very large extent soluble in water, and contains a considerable quantity of phosphoric acid and potash, the next more important base being magnesia. The amounts of carbonic acid and of chlorine are very small.

The following is Rost von Tonningen's analysis of the ash of the cocoa-seeds. Ash of the dried substance, 3·87 per cent.:—

Silica	0·99
Sulphuric acid	4·30
Chlorine	0·45
Phosphoric acid	38·18
Lime	1·94
Magnesia	trace
Carbonate of lime	44·44
" of soda	7·83
	98·13

It will appear that this analysis, although commonly quoted, is incorrect, since, according to it, no base is left to form a salt with the phosphoric acid.

THE ANALYSIS OF COCOA.

It is very seldom, indeed, that a full analysis of cocoa will be required; as already stated, the following substances enter into its composition: Water, starch, gum, fatty matter, volatile oil, red pigment, albuminous compounds, theobromine, fibre, and ash. It is only necessary to give processes for the estimation of the more important constituents—namely, the gum, starch, albuminous substances, cocoa butter, theobromine, cocoa red, and ash.

Estimation of gum.—A weighed quantity of the powdered cocoa, say five grammes, is to be repeatedly shaken with cold water, which will dissolve, besides some mineral matter, the whole of the gum present. The solution is to be filtered, and the filtrate evaporated on the water-bath nearly to dryness. Strong alcohol is added, which precipitates the gum. This is filtered through a weighed filter, washed with alcohol, dried and weighed. It is after weighing incinerated in a weighed crucible, and the mineral matter thus usually obtained is to be subtracted from the amount of crude gum.

Estimation of starch.—The quantity of the cocoa which was left insoluble in cold water is now boiled with water to burst and dissolve the starch granules. A few drops of sulphuric acid are added, and the boiling is continued for 5 or 6 hours. By this operation all starch is converted into glucose or grape-sugar, which is estimated by means of a standard copper solution, as will be found described under the head of 'Sugar.'

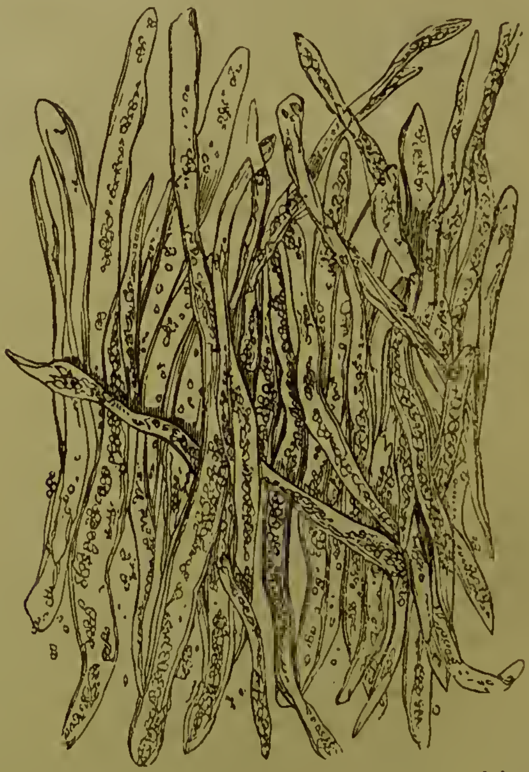
Estimation of fatty matter.—Three grammes of cocoa are dried in the water-bath and exhausted with ether. The ethereal solution on evaporation leaves the fat, which is dried and weighed. It must be borne in mind that some or all of the theobromine will be dissolved by the ether, and thus be weighed as fatty matter. The quantity of theobromine which is to be determined by the process given below is to be subtracted, therefore, from the quantity of fat extracted by means of ether.

Estimation of theobromine.—20 grammes of cocoa are boiled with a large quantity, say 1 litre, of water. The solution is allowed to cool and brought to a volume of 1 litre. The fat will mostly float on the top of the liquid. Now, take by means of a pipette 500 cc. of the decoction, and filter it through a dry filter, if necessary, repeatedly. The filtrate represents 10 grammes of cocoa. It is evaporated on the water-bath with the addition of a small quantity of magnesia, exactly as described under the 'Estimation of Theine' in Tea. The same process of estimation will therefore be applicable to both. We have ourselves employed this method, devised by Mr. Hehner, and found the theobromine obtained to be perfectly white and crystallising in beautiful needles. Theine and theobromine resemble each other very closely, and their properties are nearly identical, although the latter, as already shown, is richer in nitrogen.

Estimation of the albuminous substances.—For the estimation of the gluten a combustion for nitrogen with soda-lime has to be made. From the amount of nitrogen obtained, a quantity corresponding to the amount of theobromine found is to be subtracted. The remainder, multiplied by 6·33, gives the percentage of albuminous substances.

Estimation of cocoa red.—The method for the estimation of this substance has already been briefly given under the head of the 'Composition of Cocoa.'

Fig. 48.



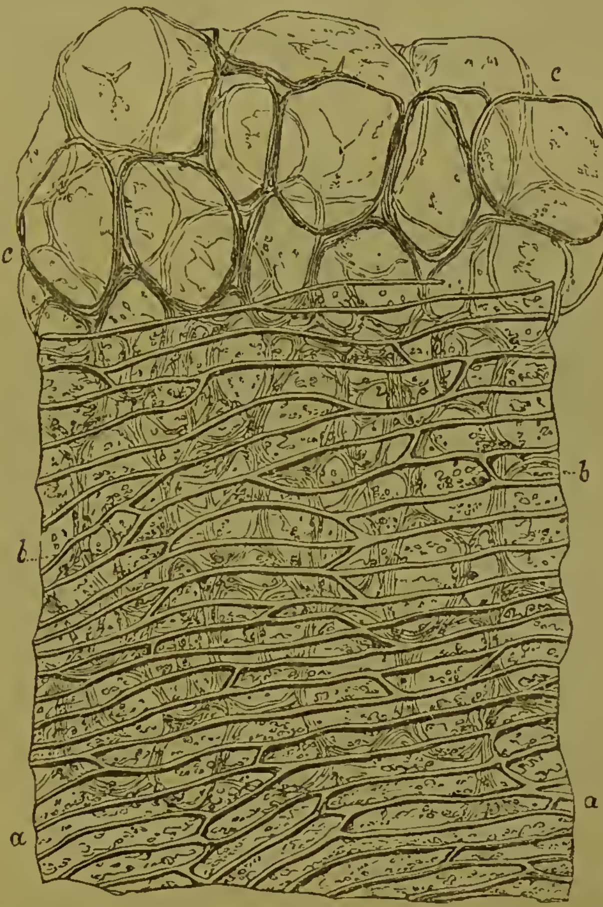
This engraving represents the ***tubular fibres*** usually observed in greater or less numbers on the surface of the Cocoa Seed. The fibres are magnified 100 diameters.

Estimation of mineral matters.—These are determined by incineration in a weighed capsule, as already described in several places.

THE STRUCTURE OF THE COCOA BEAN.

The first structure noticed on the surface of the husk consists of a considerable number of *tubular fibres* of large size, and containing granular matter and minute corpuscles; they are more abundant on some seeds than others; they do not appear to form part of the seed, but belong rather to the seed-vessel, and they are probably derived from the spongy substance which surrounds the seeds: the fibres for the most part run parallel to each other in the course of the long axis of the seed (fig. 48).

Fig. 49.



This engraving represents the *two outer tunics of the husks of the seed of* Cocoa, *together with the enlarged and mucilage-bearing cells.* *a*, outer membrane ; *b*, second tunic ; *c*, mucilage cells. This figure, as well as the three following, are magnified 220 diameters.

The *husk* may be separated into three or four distinct tunics or membranes.

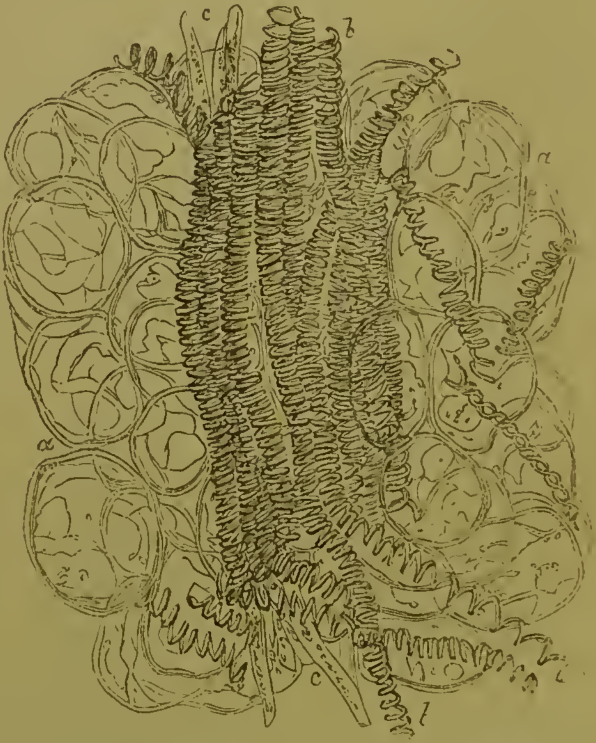
The *first or outer membrane* consists of elongated cells, adapted to each other, and disposed in a single layer, with their long diameters placed transversely to the axis of the seed.

The *second tunic* is constituted of large angular cells, superimposed in several closely connected layers; towards the centre of the membrane formed by them the cells increase greatly in size, their parietes become thin and diaphanous, and their cavities filled with a mucilaginous substance, which, in the bean soaked in water for some hours, is seen to be considerable in quantity.

These two membranes, together with the enlarged cells, are delineated in fig. 49.

As the cells forming the second membrane approach the surface of the seed, they lose their mucilaginous character, become smaller, and return to their original size.

Fig. 50.



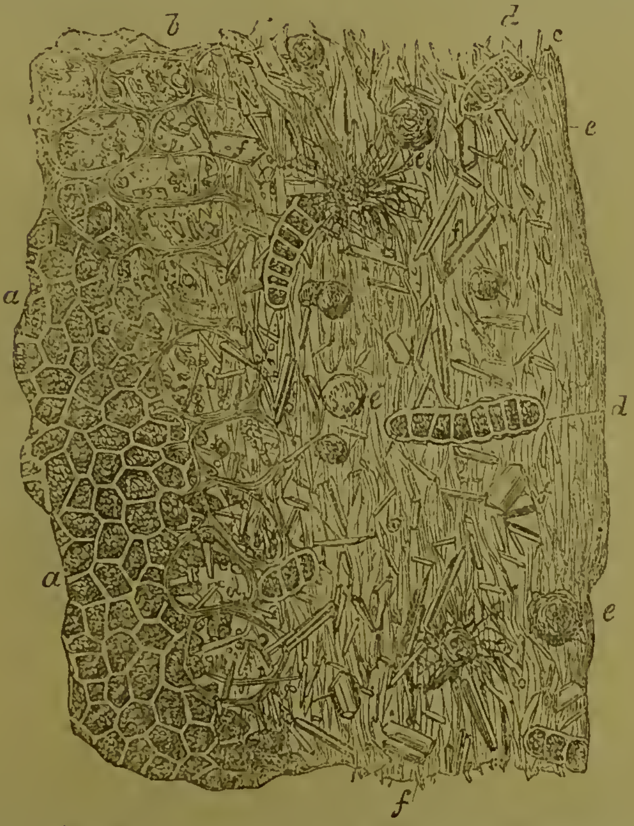
In this figure the *cells*, *woody fibres*, and *spiral vessels*, are delineated, which constitute the deep portion of the second membrane.

If now the surface of an entire seed enclosed in its membrane be examined, several raised lines or fibres will be observed, commencing at the end of the seed attached to the seed-vessel, spreading themselves out over its surface, and terminating at the distal extremity of the seed: these fibres are composed of spiral vessels, which lie imbedded in fibres of woody tissue and the cells above described (fig. 50).

The second membrane forms the chief substance and thickness of the husk.

The *third* membrane, thin and delicate, consists of angular cells of small size, the cavities of which contain minute globules of fat: in removing the outer tunics this membrane sometimes comes away in part with them, but in general the greater portion adheres to the surface of the seed. This membrane covers not only the outer surface of the lobes of the seed, but also dips down between them, and furnishes each of the opposite sides with a covering; it is most evident, however, on the external surface. It is probable, notwithstanding, it may be exhibited as a separate tunic; that it is, strictly speaking, not to be regarded as a distinct structure; but that it really belongs to the seed,

Fig. 51.

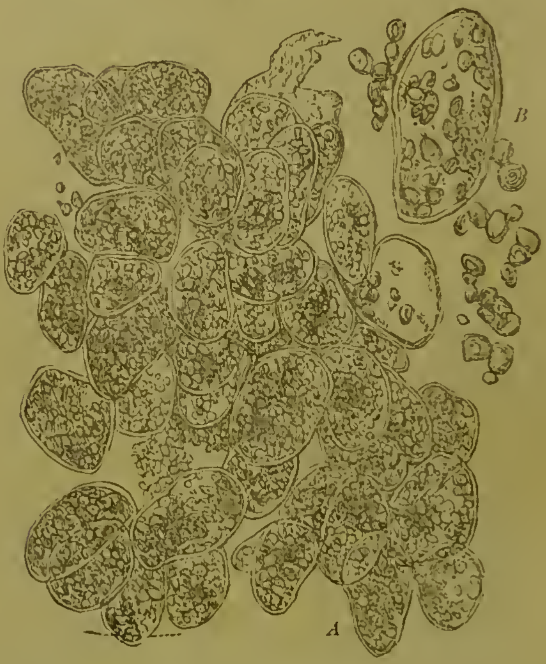


In this engraving the several structures above noticed are delineated. *a, third tunic*; *b, rounded cells*, derived from the second membrane, lying upon the fourth membrane, and situated at the lines of junction of the lobe; *c, fourth or fibrous membrane*; *d d, elongated bodies*; *e e, rounded masses of crystalline fatty matter*; *f f, crystals of margarine.*

since on removing it cells belonging to the substance of the seed frequently come away with it; the colourless cells constituting it being evidently gradually transformed into the coloured ones of the seed itself. To each seed-lobe, therefore, according to the above description, there is a distinct membrane.

Situated in the interspaces of the lobes is a fourth structure, attached externally to the second membrane, the cells forming which pass down upon it for a short distance; although clear and transparent, it exhibits a fibrous structure, and on its surface a considerable number of small crystals are always to be seen, as well as many elongated bodies, rounded at either extremity, and divided into several compartments or cells, and which do not appear to be attached to the membrane on which they lie. From their curious appearance, and the absence of connexion with any of the other structures of the cocoa-seed, the observer is led to suspect that they are extraneous and probably fungoid growths. We have detected them in every sample of cocoa-seed submitted to examination (fig. 51).

Fig. 52.



This figure represents the *cells* which form the kernel of the seed. In *A*, the cells and contained starch corpuscles are magnified 220 diameters; and in *B*, 500 diameters.

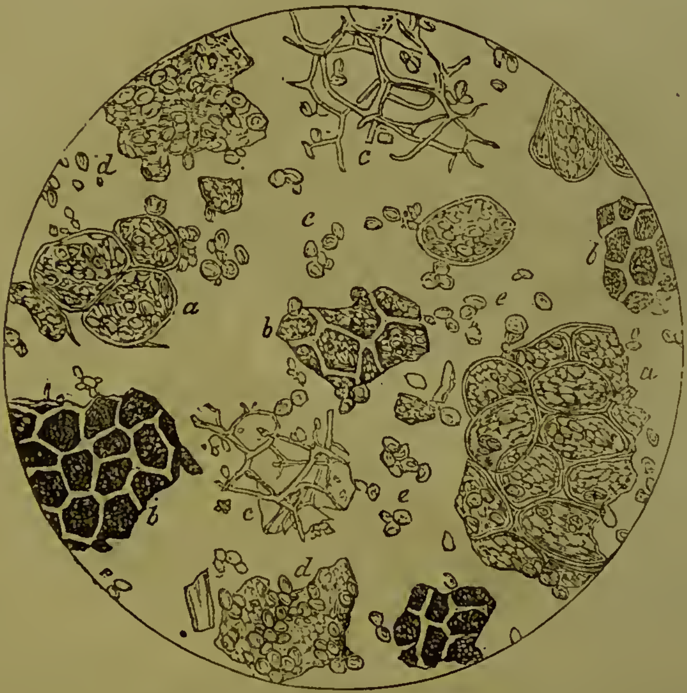
We have now completed the description of the several structures which enter into the composition of the husk of cocoa.

The *seed*, deprived of its husk, is seen to be composed of several lobes, angular in form, and irregular in size and shape; under pressure, these readily separate from each other, and the seed breaks up into pieces, which are known as 'nibs.'

The lobes are constituted of innumerable minute cells, of a rounded form, the cavities of which are filled with starch corpuscles and fatty matter (fig. 52).

On the surface of the seed these cells are rendered angular by compression, and are usually of a deep-red colour: the tint, however, varies greatly; they are frequently, in parts, spotted with purple, and even deep blue.

Fig. 53.



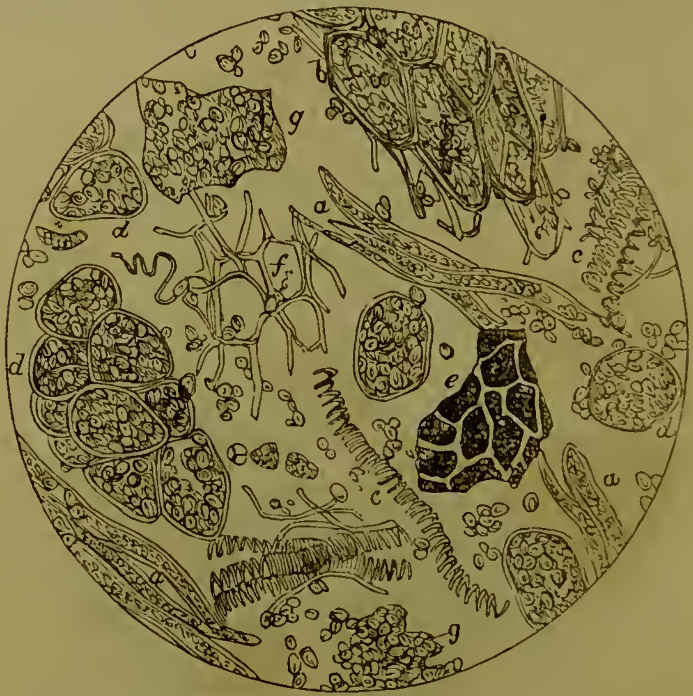
Represents the structures met with in a sample of GENUINE TRINIDAD COCOA. It will be noticed that *the tissues forming the husk of cocoa are absent*, and that those of the seed itself are much broken up, many of the cells being ruptured, so as to permit the escape of the starch corpuscles and fat, points of importance in the manufacture of chocolate. *a a*, cells of the kernel of cocoa; *b b*, membrane on surface of lobes; *c c*, tissues of embryo; *d d*, free masses of starch; *e e*, loose starch corpuscles.

Each cell contains many starch corpuscles, small in size, of a rounded form, and which often present an obscure, radiate, or stellate hilum.

Placed at one extremity of the seed is the *embryo*; this consists of cellular tissue, the cells or meshes of which enclose numerous starch granules and spherules of oil.

Now, in the more carefully prepared cocoas, the whole of the structures represented in figs. 48, 49, 50, and 51 are absent, and those delineated in fig. 52, and especially 53, only are met with: in some cases the embryo even is removed; but this, since it forms so inconsiderable a part of the entire seed, and contains, moreover, starch and fat, appears to be almost an over-refinement.

Fig. 54.



Exhibits the structures present in a sample of Flaked Cocoa, which usually *contains both seed and husk.* *a a*, tubular fibres on surface; *b b*, second membrane of husk; *c c*, spiral vessels; *d d*, cells of kernel; *e*, membrane covering lobes; *f*, tissue of embryo; *g g*, free masses of starch granules; *h h*, loose starch corpuscles.

THE PROPERTIES OF COCOA.

Cocoa may be considered under two heads; as regards its action on the nervous and vascular systems, and as a direct nutritive.

The physiological properties of the *aromatic oil* of cocoa and of the *theobromine* are probably similar to those of the corresponding constituents of tea and coffee.

The special actions of the volatile oils of tea and cocoa have not yet been scientifically investigated; those only of the oil of coffee have hitherto been made the subject of experiment; but from analogy there is good reason for supposing that all these oils, which so closely resemble each other in their physical properties, agree also in all essential particulars in their physiological actions.

The volatile oil of coffee, taken in moderate quantities, as already stated, produces a gentle excitement of the nervous and vascular systems, retards the waste of the tissues, as does also caffeine, and hence allays hunger.

The caffeine of coffee and of tea, retarding the waste of the tissues, is hence indirectly nutritive, the quantity of urea, phosphoric acid, and salt in the urine being diminished.

As a nutritive, cocoa stands very much higher than either coffee or tea, in consequence of the large quantities of fat, starch, and gluten contained in it.

It is true that tea contains a larger proportion of gluten than cocoa, but most of this gluten, owing to the manner in which the infusion is prepared and drunk, remains in the leaves, and the benefit of it is of course lost to the system. Again, tea does not contain butter or starch. In the case of cocoa, an *emulsion* of the seed is made, and in this way all the active and nutritious constituents of the article are consumed. Owing to the large quantity of oily matter present, cocoa is fattening, but is apt to disagree with some delicate stomachs.

THE ADULTERATIONS OF COCOA.

The roasted beans or seeds of cocoa, when ground and reduced to paste, constitute flake or rock cocoa, which consists, *when it is genuine, of nothing but cocoa.*

Other names under which cocoa is sold in this country are granulated, soluble, dietetic, homœopathic, &c.

Now there is nothing in these names to indicate that the articles in question are anything more than varieties of cocoa, or to show, what is too frequently the case, that they are compounds of sugar, starch, cocoa, and oftentimes other substances.

The practice of calling these *mixed* articles COCOA is manifestly as improper and deceptive as it is to call *the compound of coffee and chicory,* Patent Compressed Coffee, Finest Old Turkey Coffee, &c.

An article should be sold for what it really is, and under its own name; if it be right to sell these mixtures at all, they should be sold as the law now compels chicory and coffee to be sold, and should be labelled as mixtures. Further, the proportions of the several ingredients entering into the composition of the mixed article should be stated on the wrappers.

The French and other continental manufacturers of cocoa adopt a more straightforward and proper course: they never call their compound and manufactured articles cocoa, but chocolate; thus they eve denominate the cakes which they prepare, and which contain nothing but cocoa, 'chocolat sans sucre,' although with strict propriety, they might in this case have used the word cocoa.

The cocoa, then, of the English makers in general is not cocoa at all; whenever, therefore, the word cocoa, to which an adjective o indefinite signification is prefixed, is employed to designate an article which is not pure or genuine cocoa, *that article ought to be considere as adulterated.*

The works of Accum, Brande, Ure, and Pereira contain but little information respecting the adulteration of cocoa; the only English writers who have treated of it at all fully being Mitchell and Normandy.

The first of these authors, Mitchell, has the following observations on the subject:—

'Chocolate is adulterated with flour, potato starch, and sugar, together with cocoa-nut oil, lard, or even tallow. Even the so-called finest chocolate is made up with clarified mutton suet and common sugar, together with ordinary cocoa.

'If in breaking chocolate it is gravelly—if it melt in the mouth without leaving a cool, refreshing taste—if it, on the addition of hot water, becomes thick and pasty—and, lastly, if it form a gelatinous mass on cooling, it is adulterated with starch and such-like substances.

'Where earthy and other solid substances are deposited from chocolate mixed with water, either the beans have not been well cleansed, inferior sugar has been employed, or mineral substances have been added to it, either for the purpose of colouring or of increasing its weight.

'Moreover, when chocolate has a kind of cheesy taste, animal fat has been added; and when very rancid, either vegetable oil, or even the seeds themselves, have been employed in the sophistication.

'The mineral substances employed in the making up of chocolate are some of the ochres, both red and yellow, together with minium (red lead), vermilion, sulphate of lime, chalk, &c. Chocolates so adulterated, more especially with the preparations of lead, are highly injurious; it is, however, only the inferior chocolates that are thus adulterated.'

From the work of Normandy we extract the following remarks:—

'Unfortunately, however, many of the preparations of the cocoa-nut sold under the names of chocolate, of cocoa flakes, and of chocolate powder, consist of a most disgusting mixture of bad or musty cocoa-nuts, with their shells, coarse sugar of the very lowest quality, ground with potato starch, old sea-biscuits, coarse branny flour, animal fat (generally tallow, or even greaves). I have known cocoa powder made of potato starch, moistened with a decoction of cocoa-nut shells, and sweetened with treacle; chocolate made of the same materials, with the additions of tallow and of ochre. I have also met with chocolate in which brick-dust or red ochre had been introduced to the extent of 12 per cent.; another sample contained 22 per cent. of peroxide of iron, the rest being starch, cocoa-nuts with their shells, and tallow. Messrs. Jules Garnier and Harel assert that cinnabar and red lead have been found in certain samples of chocolate, and that serious accidents had been caused by that diabolical adulteration. Genuine chocolate is of a dark brown colour; that which has been adulterated is generally redder, though this brighter hue is sometimes given to excellent chocolate, especially in Spain, by means of a little annatto. This addition is unobjectionable, provided the annatto is pure, which, however, is not always the case.'

Do Sugar and Starch render Cocoa Soluble?

In defence of the practice of selling sugar, flour, and cocoa under the name of cocoa, it is alleged that these articles render the cocoa *more soluble and more digestible* than it would be alone. In reference to these statements the following considerations present themselves.

When a cup of cocoa is made by pouring hot water upon it, the sugar of course dissolves, as when added to tea or coffee: but the sugar certainly has no effect whatever in making the cocoa more soluble or more digestible; and the consumer at all events might be left to add it for himself as he does to his tea or coffee. The starch or farina usually added to cocoa, when boiling water is poured upon it, forms a paste or jelly, only partially cooked, and more or less thick. This serves to entangle the particles of cocoa-oil, and to prevent them from ascending to the surface, and collecting there in droplets. In a cup of cocoa, therefore, for an equal quantity of cocoa, there is just as much oil as though no starch were present, although, it is true, part is concealed from view. So far from rendering cocoa more digestible, the starch, being only imperfectly cooked by the boiling water, really has a contrary effect. Of course the more sugar and starch added to the cocoa, the less cocoa there is in the mixture and the less oil; but nearly the same end would be obtained by using less of genuine cocoa. Moreover, starch in the proportion of about 12 per cent. is one of the natural constituents of the cocoa bean.

But it may be granted, merely for the sake of argument, that the starch (the sugar is altogether out of the question) is really an improvement, but it can only be so in certain proportions; yet when we come to analyse different preparations of cocoa we find that the proportions of starch vary from 5 to 50 per cent. and with the sugar from 80 to 90 per cent. Of course such large additions as these cannot possibly constitute improvements; in fact, some of these mixtures have scarcely the flavour, or even the smell, of cocoa.

That these large additions of starch and sugar are not improvements, anybody may satisfy himself by contrasting the smell and taste of a cup of cocoa made from genuine flake or rock cocoa, and one made from the ordinary mixed article.

Nevertheless, we do not go the length of stating that such mixtures ought not to be permitted; but we are of opinion that they should be sold as mixtures, and the proportions of the ingredients stated on the wrapper.

Kinds of starch employed.—Nearly every kind of flour and starch, especially such as are inexpensive, is added to cocoa. In the cheaper descriptions of cocoa *wheat flour, potato starch, and sago meal* are chiefly used, as well as mixtures of them in different proportions; one dealer giving the preference to one kind of starch or mixture, another to another kind. In some of the more expensive cocoas *East Indian arrowroot* and *Tous les mois,* or mixtures of these with the cheaper starches, are employed.

Quality of sugar employed.—The quality of the sugar used varies from white lump to the inferior descriptions of brown and treacly sugar.

Adulteration with animal fat.—Now the excessive reduction of cocoa by means of sugar and starch sometimes renders the employment of animal fat necessary to give it a richer character.

The real secret of the almost constant use of starch and sugar is to be found in the cheapness of these articles, and not in any advantages supposed to be derived from their admixture with cocoa; this we shall now proceed to show.

Genuine cocoa, in the form of flake, rock, or roll, is sold at about 1*s.* 6*d.* per pound; wheat flour may be purchased at 1½*d.*, potato flour and sago meal at about 3*d.* or 4*d.* per pound; sugar at from 3*d.* to 5*d.* per pound. The mixtures of cocoa, starch, and sugar are sold at from 6*d.* to 2*s.* 8*d.* per pound. Let the reader compare these prices with the cost of wheat and potato flours, and he will then perceive what a field for imposition and extortion the admixture of these substances with cocoa affords.

Setting aside, however, the question of price, and whether the admixture of starch with cocoa is attended with any advantages or not, on the same principle as we objected to the calling of the mixture of chicory and coffee—coffee, we also object to designating a compound of starch, sugar, and cocoa by the name of the latter only, no adjective being prefixed to the word cocoa, indicating the presence in the article of any other substances.

Adulteration with chicory.—But there are other adulterations of cocoa sometimes practised, but which have not yet been referred to, viz., those with *chicory* and the *husk of cocoa.*

The cocoa beans are sometimes coarsely broken up into nibs, and are sold in this state; now these nibs are frequently adulterated with roasted chicory root.

Adulteration with husk of cocoa.—Again, genuine cocoa of good quality ought not to contain any of the husk, which, as has been shown, forms about 13 per cent. of the seeds, and which is almost destitute of active and nutritious principles.

Nevertheless the husk is almost constantly present in the cheaper cocoas of British fabrication: the French makers rarely make use of the husk, but sell it at about 3*d.* per lb.

There is good evidence to show that in some cases the fragments of husk prove irritating to the intestines and occasion diarrhœa.

Johnston states: 'This husk is usually ground up with the ordinary cocoas, but it is always separated in the manufacture of the purer chocolates. Hence, in the chocolate manufactories it accumulates in large quantities, which are imported into this country from Trieste and other Italian ports under the name of "miserable." Here the husk is partly ground up in the inferior cocoas, and is partly despatched to Ireland.'

Mr. George Phillips, in evidence before the Parliamentary Committee on Adulteration, in 1855, stated:—'In one case, where I succeeded in getting the proportions, from a manufacturer, of what he called his best soluble cocoa, there were, in his own language, cocoa 42, lump 42, white and red 52. The cocoa represents the nut, the lump the sugar, and the white is starch; the red, oxide of iron to colour it. The percentage of cocoa in that sample would be 30 per cent., and that was stated by the manufacturer to be his *best soluble cocoa.*' If that was his best cocoa, what, we wonder, was the composition of his worst?

The adulteration with Venetian red and other ferruginous earths.—Venetian red and other ferruginous earths have been long employed in the adulteration of cocoa in order to restore the colour reduced by adulteration with large quantities of starch and sugar. As we have seen, Mitchell, Normandy and Phillips all refer to this practice, and the former states that *red lead* and *vermilion* have been sometimes employed.

It should be known that Venetian red and other ferruginous earths are sometimes contaminated with *arsenic.*

Adulteration with chalk.—This substance has been occasionally used in the adulteration of cocoa, as also sulphate of lime or gypsum. Although formerly employed, especially the chalk, it is rare to meet with either of them in the present day.

Results of the Examination of Samples.

We will now state *the results derived from the examination, chemical and microscopical, of a large number of samples of cocoa* of different kinds purchased from dealers resident in the metropolis, and made some years since.

The results of the examination of fifty-four samples of various kinds were—

That *eight* samples were *genuine,* these being *flake* and *rock* cocoas;

that is, they contained no sugar or starch, but consisted entirely of cocoa.

That *sugar* was present in forty-three samples, the amount forming from 5 to as much as, in some cases, 50 per cent. of the article.

That *starch* was detected in forty-six of the so-called cocoas, the amount likewise varying from 5 to 50 per cent.

To such an extent did some of the samples consist of sugar and starch, that they contained only sufficient cocoa to impart some degree of flavour to the articles.

Lastly, that out of sixty-eight samples of cocoa and chocolate, the *ashes* of which were submitted to examination, thirty-nine contained coloured earthy substances, as *reddle, Venetian red, umber*, &c.

When it is remembered that the relative prices of wheat flour, potato starch, and sago meal, also of sugar, especially brown sugar, bear so small a proportion to that of the cocoa itself, it will be readily understood how great is the inducement to substitute these articles for cocoa; and it will, we are sure, be apparent that it is not out of simple regard to our digestive organs that they are added to cocoa in such large quantities.

The extent to which the adulteration of cocoa is carried may be judged of by the fact that the price at which some of the inferior cocoa mixtures are sold is much less than that at which genuine cocoa can be purchased.

Before proceeding to point out the methods by which the various adulterations of cocoa may be discovered, a few remarks may be made on chocolate.

CHOCOLATE.

Unlike cocoa, chocolate is, as is well known, a manufactured article: the French particularly excel in its preparation, making a variety of combinations of cocoa with other substances.

The more common additions are, however, sugar and various kinds and mixtures of starch; in the better descriptions of chocolate, Maranta arrowroot is employed.

For imparting flavour and scent, vanilla and cinnamon are chiefly used.

Occasionally a medicinal chocolate is prepared with salep, a fecula obtained from the bulbous root of an orchis. In some cases, also, chocolate is made the vehicle for the administration of various remedies, the taste of which is to a great extent concealed thereby.

Of Twelve samples of chocolate examined,

One contained 13 parts of sugar and 25 parts of starch to the 100 parts; the starch consisted of a mixture of tapioca starch, Maranta arrowroot, Indian corn flour, and sago meal.

The *second*, of 35 parts sugar and 30 parts wheat flour per cent.

The *third*, of 13 parts sugar and 10 parts sago to the 100 parts.

The *fourth* sample, being obtained from the same maker, had the same composition as the first.

The *fifth* contained 15 per cent. of a mixture of wheat flour and potato starch, but no sugar.

The *sixth* contained 14 per cent. of sugar and 16 of potato flour.

The *seventh* consisted of 14 per cent. of sago meal, with a little sugar, the remainder being cocoa.

The *eighth* of a mixture of cocoa and sugar made into a paste with water, the cocoa forming about 56 per cent. of the article, or little more than one-half.

The composition of the *ninth, tenth,* and *eleventh* samples was nearly the same.

The *twelfth* sample was made up of a mixture of sugar, potato flour, sago meal, water, and cocoa. The sugar and water formed 42 parts of the article, the flour at least 10 parts; the cocoa thus formed less than half the article.

Besides the above ingredients, several of the chocolates contained *coloured ferruginous earths.* Generally the proportion of starch was much less than in some of the cocoas examined.

Chocolate being a compound article, no valid objection can be urged against the presence of sugar and starch, provided the composition is acknowledged. The points to be considered are, the price of the article, and the proportions and quality of the ingredients of which it is composed; the addition of the red earths of course cannot be justified.

ON THE DETECTION OF THE ADULTERATIONS OF COCOA.

The articles employed in the adulteration of cocoa, and with the means for the detection of which it is necessary that we should be acquainted, are the following: various *flours* and *starches, husk of cocoa, chicory root, fatty matter, sugar,* and *coloured ferruginous earths.*

On the detection of starch by means of the microscope.—The only certain method by which a knowledge of the kind of starch employed can be obtained is by means of the microscope. In some cases, however, it is necessary to ascertain the quantity of starch present.

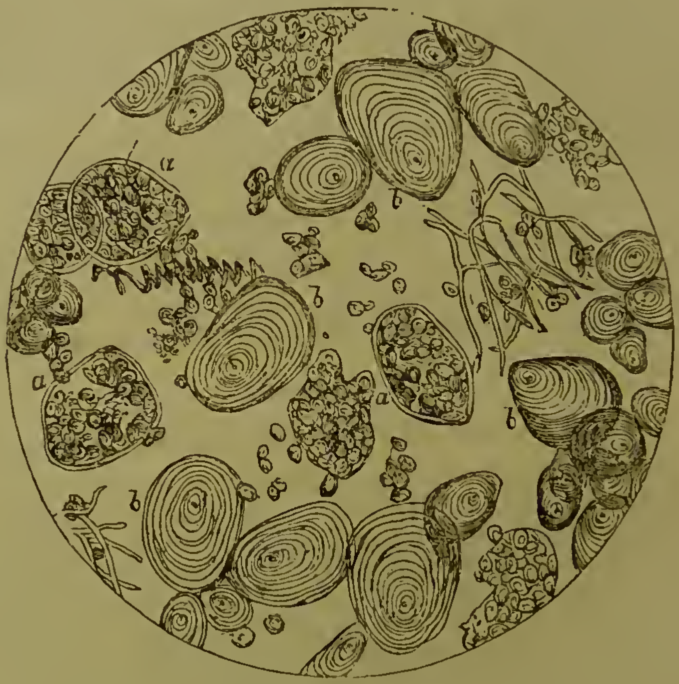
The principal starches employed in the adulteration of cocoa are the following:—Wheat flour, potato flour, Indian corn, sago meal, tapioca, East India, Maranta, and Tous les mois arrowroots. Now, all these starches possess characters by which they may be readily distinguished from each other by the aid of the microscope.

It must be remembered, however, that cocoa itself contains about 11 per cent. of starch in the form of minute starch granules, entirely different in size and shape from all those starches which are employed in the adulteration of cocoa; besides, the starch granules of cocoa usually are not free, but are for the most part imbedded in the cells of the cocoa, or else in its butter.

Now, although cocoa contains so much starch, the only means formerly recommended by writers for the discovery of the adulteration of cocoa with starch was by iodine, which of course gives, if properly employed, indications of the presence of fecula in every case; and not a word was even hinted respecting the employment of the only means by which the different starches used could be identified—namely, the microscope—until we ourselves pointed out the importance of the use of this instrument in all such cases.

The characters of *wheat flour* will be minutely described under the head of 'Flour;' but they have already been briefly noticed and represented when describing the adulterations of chicory and coffee (figs. 40 and 46).

Fig. 55.



SUPERIOR SOLUBLE COCOA.

a a a, starch corpuscles, cells, and spiral vessels of cocoa; *b b b*, granules of *potato flour*.

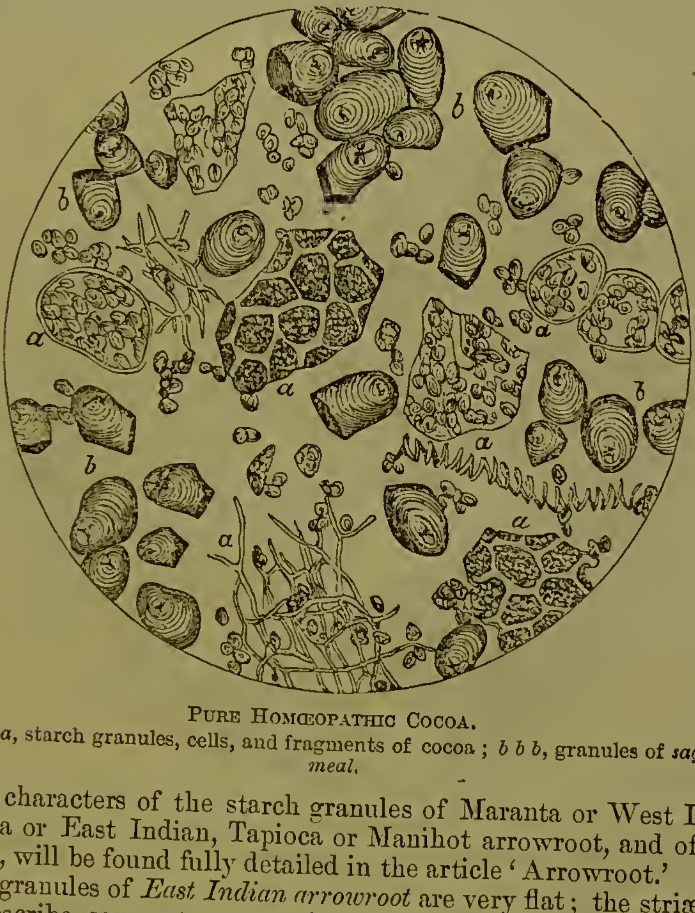
The characters of *potato flour* will be described under the head of arrowroot. It may be stated now that they are of large size, ovate form, plainly ringed, and with a very distinct hilum at the smaller extremity of each granule. They are well represented in fig. 55.

The characters of *sago meal* will also be given under the head of 'Sago.' The granules, although smaller than those of potato, are yet of considerable size; but they are easily distinguished by being truncate at one extremity, as represented in fig. 56.

In fig. 57 the starch granules of *potato flour* and *sago meal* are delineated: it will be seen that the differences are very considerable and obvious.

The starch granules of *Indian corn* are of about the size of those of wheat flour; but the greater number of them are polygonal, and hence they exhibit a more or less angular outline. See article 'Flour.'

Fig. 56.



PURE HOMŒOPATHIC COCOA.
a a a, starch granules, cells, and fragments of cocoa; *b b b*, granules of *sago meal.*

The characters of the starch granules of Maranta or West Indian, Curcuma or East Indian, Tapioca or Manihot arrowroot, and of Tous les mois, will be found fully detailed in the article 'Arrowroot.'

The granules of *East Indian arrowroot* are very flat; the striæ upon them describe segments or portions of rings only; and the central cavity is not visible.

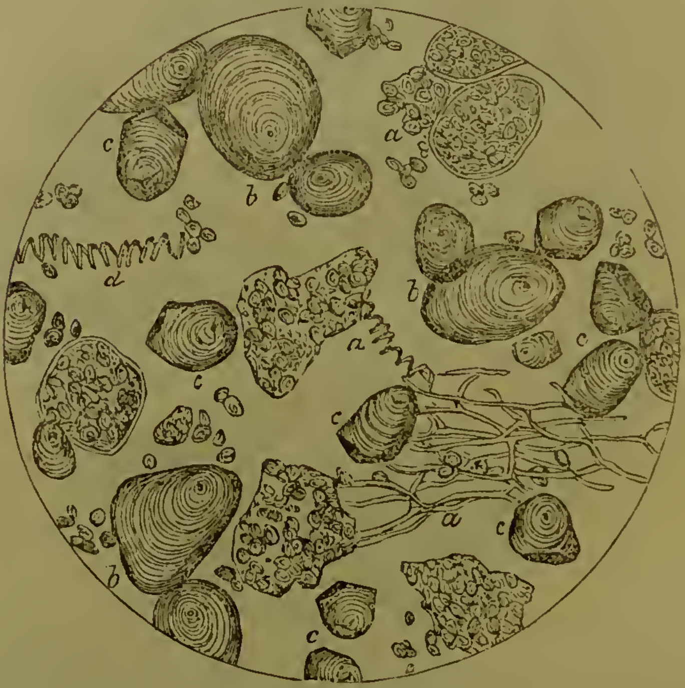
The starch granules of *West Indian arrowroot* are of nearly the same size as those of sago starch. They differ, however, in not being muller-shaped, and in the slit hilum which runs transversely across the granule.

Those of *Tapioca arrowroot* are, like the starch granules of sago, muller-shaped, but they are several times smaller.

Lastly, the starch granules of *Tous les mois* differ from all the others in being very much larger; they are flat, with strongly-marked striæ, which describe segments of circles only, and they present a small but well-marked central hilum (fig. 58).

On the detection and estimation of starch by chemical means.—The detection of starch in cocoa may be effected in two ways: either by taking a minute quantity of the suspected cocoa, diffusing it in water, and placing it, after the addition of a small quantity of a solution of iodine, under the microscope, when the starch granules, whether natural or foreign, will be, of course, revealed by the blue colour of the iodide of starch; or the iodine may be added to a decoction of the cocoa, when the whole solution will exhibit, more or less strongly, the characteristic blue colour.

Fig. 57.



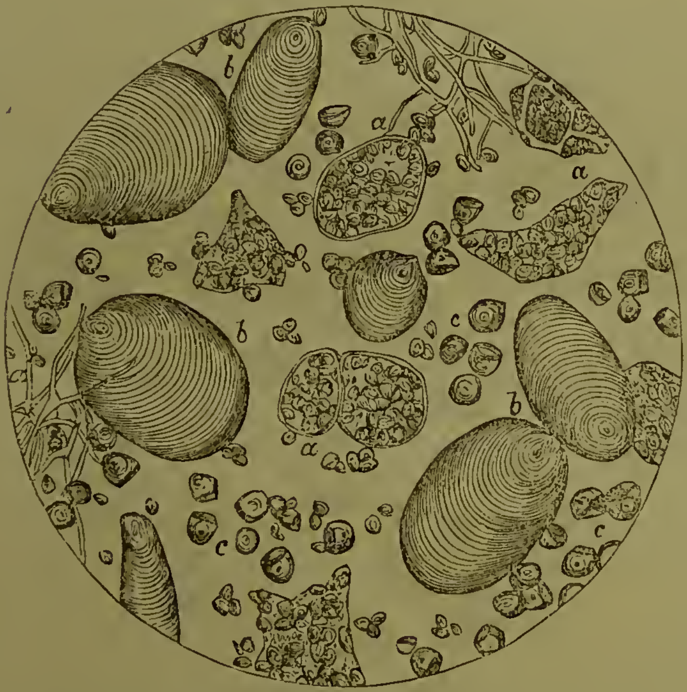
Celebrated Soluble Cocoa.

a a a, granules and cells of cocoa; *b b b*, granules of *potato flour*; *c c c*, granules of *sago meal*.

To effect a quantitative estimation of the starch, the sugar, which is often present together with starch in adulterated cocoas, must be first removed by means of cold water. A decoction of one or two grammes of the cocoa which has been deprived of the sugar is made, and allowed to cool, in order that the fatty matter may become solid and admit of being for the most part readily separated. The decoction is then boiled for five or six hours with a few drops of sulphuric acid, until all the starch has become converted into glucose, which is then determined by means of the copper solution. 100 parts of glucose correspond to 90 parts of starch. Allowance must, of course, be made for the starch naturally present in cocoa, amounting to about 11 per cent.

On the detection and estimation of sugar.—The presence of sugar in cocoa may be readily detected by the taste. To determine the quantity, the following simple but efficient proceeding may be adopted. Dissolve a weighed quantity of cocoa containing sugar in cold water, filter, and then dry the residue in the water-bath, and weigh; the water is to be estimated in a second sample, and subtracted from the quantity first obtained. The difference will represent approximately the percentage of sugar, but a deduction of about 7 per cent. of the cocoa present must be made for the extraction of other soluble matters from

Fig. 58.

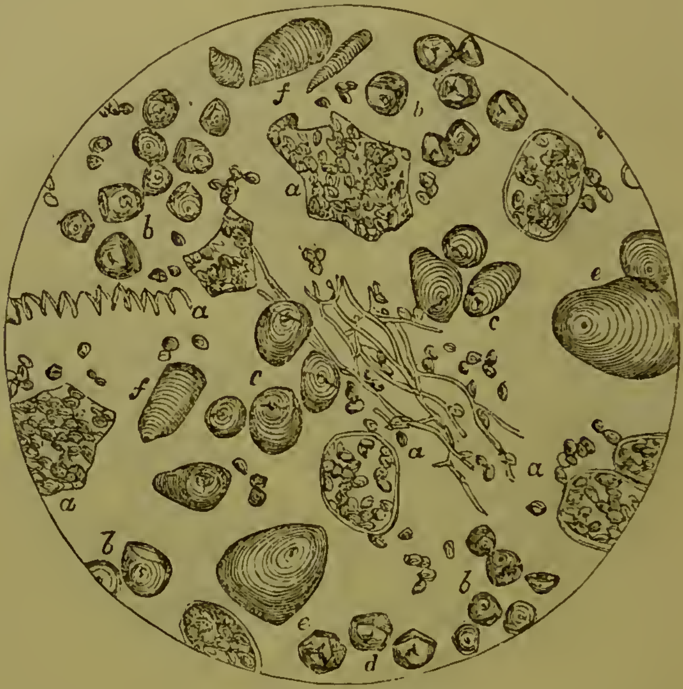


So-called Homœopathic Cocoa.
a a a, granules and cells of cocoa; *b b b*, granules of *Canna starch* or *Tous les mois*; *c c*, granules of *tapioca starch*.

the cocoa itself, as gum, &c. The method of determining the sugar by conversion into alcohol and carbonic acid is not applicable to the cocoa mixture, because of the starch present; but the sugar may be dissolved out by means of water converted into glucose, by boiling with dilute sulphuric acid, and then estimated by the copper solution in the manner fully described under the head of 'Sugar.'

On the detection of foreign fat in cocoa.—The best and simplest method of proceeding is to take from 50 to 60 grammes of cocoa, dry

Fig. 59.



SO-CALLED GENUINE UNADULTERATED CHOCOLATE.

a a a, starch granules and cells of cocoa; *b b b*, granules of *tapioca starch*; *c c c*, *Maranta arrowroot*; *d*, *Indian corn meal*; *e e*, *potato starch*; *f f*, *Curcuma arrowroot.*

in the water-bath, and remove the fat by means of ether; evaporate the ethereal solution, when the fat will be obtained in a pure state; determine the melting point of this in the manner described in the article on the adulteration of 'Butter.' The fusing point of pure cocoa butter thus determined is nearly that of ordinary butter and is 35° C., while the fusing points of all animal fats likely to be employed in the adulteration of cocoa are many degrees higher. Thus the tables given in the article on 'Butter' may be employed to detect the adulteration of cocoa with animal fats. Furthermore, if the fat thus separated have a high melting point, it will, unlike cocoa butter, become rancid and tallowy in the course of a few days.

On the detection of mineral substances.—Of the mineral substances employed in the adulteration of cocoa, some are used, as already pointed out, for the sake of their weight; of these the chief are *carbonate of lime* or *chalk*, and *hydrated sulphate of lime*, especially the former.

Other substances are employed for the colour they impart, and these are frequently had recourse to; the principal are red iron earths, as *red ochre*, *Venetian red*, and *umber*.

For the detection of these substances 10 grammes of the cocoa should be incinerated, and the ash weighed and analysed.

For the detection of *carbonate of lime* and *sulphate of lime* we must proceed as described in the article on 'Tea.'

The ash of genuine cocoa is pale grey: but if any of the red iron earths be present, it will be more or less coloured with the red oxide of iron; and in order to determine the quantity of this, the process described in the articles on 'Tea' and 'Chicory' must be followed.

Red ochre consists of sesquioxide of iron with silica, and sometimes alumina, clay, or even chalk; and *Venetian red*, when genuine, of the same oxide; it is obtained by calcining copperas or sulphate of iron, but it is often adulterated, especially with chalk.

It should be known that the colour of the ash obtained by the incineration of preparations of cocoa, adulterated with red ochre, is subject to considerable variation, dependent on the manner in which the incineration has been conducted; whether in an open or covered crucible, and according to the degree to which the ash has been heated and the length of time it has been subjected to the heat. Thus the ash of cocoa so adulterated may be made to assume different colours, varying from dark brown, light brown, fawn, yellow, ferruginous yellow, up to rust-red, according to the method of incineration.

In some of the samples in which *clay* and *sulphate of lime* have been detected, these substances were not used for the sake of adding bulk or weight to the cocoa, the quantity present being too small; but they no doubt entered into the composition of the earthy colouring matters employed.

Alumina, if present, may be estimated from the soda or potash solution used to separate the alumina from the iron in the manner directed for the determination of alum in 'Bread.'

The following question, addressed to Mr. George Phillips by a member of the Parliamentary Committee on Adulteration in 1855, with the reply thereto, will show how admirably the Revenue was protected, some years since, by the Excise against loss from the adulteration of cocoa:—

Mr. Kinnaird: 'Have you examined any cocoas?'

Reply: 'Though that is under us, we have not much to do with it;' and then follows a statement of the inability of the Excise to detect Venetian red, or any other ferruginous earth, although this is one of the commonest of the adulterations to which cocoa is liable.

To show to some extent the great evil of the sale of mixed articles, such as cocoa, unaccompanied by any specification, either that they are mixed articles, or as to the proportions of the ingredients entering into the composition of the mixture, the evidence of Mr. S. Cadbury, the cocoa manufacturer, as given before the Parliamentary Committee of 1874 on the subject of the adulteration of food, may now be quoted:—Q. Does the bulk of the manufactured cocoa, as supplied to the British public, contain less than one-fourth of the bean? A. So we believe by what is tested.—Q. What are the remaining three-fourths composed of? A. Of starch and sugar.—Q. Does starch render the compound thick, heavy, and indigestible? A. Yes, so medical men assert, and so we believe.—Q. Is the chocolate manufactured in France superior to that made in this country as a rule? A. It is, for this reason—that in France the percentage of starch added has to be stated on the package or on the cake. In this country there is no such law.—Q. Would you have a similar label applied to the articles in England? A. We believe that it would ultimately be to the advantage of the trade, and would be to the advantage of the public.—Q. But you think that simply saying, 'This is a compound mixture of cocoa and other ingredients' is not sufficient without stating some percentage? A. It is not sufficiently definite. Some makers might have only a tenth part of cocoa in the mixture sold as cocoa. Others might have 50 per cent. as the law now stands.—Q. You would suggest that nothing should be sold as cocoa except the cocoa bean or preparations made without any admixture? A. We believe that it would be to the benefit of the public and of the manufacturer also.—Q. And the mixed article you would call chocolate? A. Yes.—Q. Would you apprehend that the cheap starches were more indigestible than the better sorts? A. We believe that all starch is indigestible without being boiled; either eaten in the form of chocolate, where starch is added, it is indigestible, or taken in solution as soluble cocoa, which can be prepared without being boiled, it is also indigestible.—Q. Could you say why starch is not nutritious and beneficial to the system? A. Because starch contains no nitrogenous principle, which is the valuable part of cocoa, and consequently it is not so valuable as an article of nutrition.—Q. If the starch were left out altogether, could the cocoa be manufactured? A. We believe that it would be a much better and more wholesome article without it.—Q. We have had a good deal of evidence about cocoa. Do you yourself see any difficulty in the manufacture of pure cocoa? A. None at all.—Q. Can it be used free from any admixture? A. It can, and it is used very largely.—Q. If we have had information from other houses that it was impracticable and could not be used, that would be incorrect? A. Incorrect entirely.—Q. And you think, do you, that the starch has no particular effect upon it as an article of diet? A. We believe it has an injurious effect. It causes the prepared cocoas to which the starch is added often to disagree with thousands of people.—Q. What is your experience that it is wholesome or unwholesome? A. We believe it is not wholesome unless it is boiled, and very much of the cocoa that is used is not boiled; it simply has boiling water poured upon it.—Q. But boiling water poured upon the mixture of starch would have the same effect upon it, would it not? A. It does not break the globules of starch by simply pouring boiling water upon it. It has to be boiled to break the globules.—Q. Do you state that of your knowledge? A. I take that from an eminent chemist whose advice we took upon the question.

Another witness, Mr. Bartlett, the analytical chemist, was asked, 'What is your opinion of cocoa?' and he replied, 'From my inquiries and from my analyses I am strongly of opinion that any addition to cocoa is a detriment and is an adulteration; that the mixed article is greatly injured as an article of nutriment, and that it is also injured as a matter of taste.' Q. Do you think that starch is indigestible unless it is boiled? A. Undoubtedly, highly indigestible, unless it is boiled.

Another chemical witness, Mr. Wanklyn, gives the following evidence. He is asked, 'Take cocoa; what is your opinion about that being mixed?' 'Cocoa in an unprepared state would not be a saleable article in this country. It requires to be altered or to be mixed in order to make it saleable.' How is this reply to be reconciled with the fact that a very large proportion of the cocoa now made and sold is unmixed and genuine? Let the reader furnish the answer. Q. Is it your opinion that the starch which is mixed with cocoa is indigestible unless it is boiled? A. No, I do not think so.—Q. You think that simply pouring water upon it is sufficient to make the starch readily digested? A. It is sufficient, I think.

CHAPTER VIII.

SUGAR AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any added substance, either vegetable or mineral.

In the present article we have to treat principally of *Cane Sugar*, as derived from the sugar-cane and some other plants and trees, since it is the kind of sugar chiefly employed for domestic purposes. It is necessary, however, that we should also describe another variety—namely, *Glucose*, which occurs mixed up more or less with cane sugar, and since the latter is easily and by natural causes converted into the former.

The various kinds and modifications of sugar are, chemically, divisible into *fermentable* or *true sugars*, and into *nonfermentable sugars*, sometimes termed *saccharoids*. The first description is further divisible into two groups, to the first of which belong *dextrose*, *lævulose*, and *galactose*, all having the formula $C_6H_{12}O_6$; to the second, *saccharose* or *cane sugar*, *lactose* or *milk sugar*, and some other varieties which it is unnecessary for us to notice, and having the formula $C_{12}H_{22}O_{11}$.

The nonfermentable sugars include, amongst several others, *sorbite*, *inosite*, and *mannite*.

Dextrose or dextroglucose, $C_6H_{12}O_6$. Ordinary glucose, grape, fruit, honey, starch, and diabetic sugars, all contain this description of sugar. It occurs abundantly in fruits, often together with cane sugar, and nearly always with lævulose. It separates from its aqueous solution in white opaque granular hemispherical masses, having two molecules of water of crystallization. But from alcohol of 90 per cent. it crystallizes in anhydrous microscopic needle-like crystals. It is much less soluble in cold water than cane sugar. In boiling water it dissolves in all proportions, forming a syrup which has a very sweet taste. It is also less soluble than cane sugar in alcohol. According to Prout 2·5 parts of glucose sweeten as much as 1 part of cane sugar. It turns the plane of polarization to the right, and hence its name.

Lævulose or lævoglucose, $C_6H_{12}O_6$, is distinguished from the previous kind of sugar by its turning the plane of polarization to the left. The mixture of lævulose and dextrose in equal atomic proportions constitutes *inverted sugar*; it is made by the action of acids on cane sugar, and is lævo-rotatory at ordinary temperatures, because the rotatory power of lævulose is greater than that of the dextrose, but at higher temperatures it becomes dextro-rotatory. Lævulose is a colourless, uncrystallizable syrup-like substance; it is as sweet as cane sugar, exerts a purgative action, and is more soluble in alcohol than dextrose.

Mixtures of dextrose and lævulose in unequal quantities exhibit, according to the proportions in which they are mixed, dextro or lævo-rotation, as is seen in the case of honey and fruits.

Galactose is obtained by the action of dilute sulphuric acid upon milk sugar; it stands, therefore, to the latter in the same relation as does invert sugar to cane sugar.

We now come to the second class of fermentable sugars, including especially saccharose or cane sugar, and lactose or milk sugar. The latter will be treated of under the head of 'Milk.'

Saccharose or *cane sugar*.—This description of sugar is very widely distributed throughout the vegetable kingdom, especially in certain herbs belonging to the natural family *Graminaceæ* or the grasses. Thus the stems of the sugar-cane, *Saccharum officinarum*, contain as much as 20 per cent.; the *sorgho*, or Chinese sugar-cane, *Sorghum saccharatum*, from 9 to 10 per cent.; the stems of *maize*, *Zea mays*, from 3·5 to 4 per cent. of the juice, together with about the same amount of glucose. Again, cane sugar is abundant in certain roots belonging to the natural family *Umbelliferæ*, as those of the *carrot*, *parsnip*, but particularly *beet*, *Beta vulgaris*, which contains from 7 to 11, and even 14 per cent. It occurs likewise in the stems of certain species of *birch* and *maple*, especially the *sugar maple*, *Acer saccharinum*, which grows spontaneously in many parts of North America, including New York and Pennsylvania; and of several kinds of *palm*, including *Arenga saccharifera*, *Saguerus Rumphii*, and *Borassus flabelliformis* or the Palmyra tree, *Caryota urens* or the *kitul* tree of Ceylon, which furnishes the sugar styled *jaggery*, and the *Cocos nucifera* or cocoa-nut tree.

In most fruits saccharose occurs together with inverted sugar, while certain nuts, as the walnut, hazelnut, and almonds, contain cane sugar unmixed with inverted sugar. Honey likewise contains saccharose.

Lastly, *manna*, derived from *Tamarix mannifera*, yields as much as 50 per cent. of cane sugar, 25 of inverted sugar, and 20 of dextrin.

PREPARATION OF SUGAR.

From the cane.—The canes, when ripe, are cut down, stripped of their leaves, and the juice expressed by means of rollers. The juice thus obtained is heated in copper boilers to about 60° C., a small quantity of lime being added. The impurities rise to the surface and are removed as they collect. The juice thus clarified is first concentrated to about 23° of the hydrometer, is filtered through cloth and further evaporated to a thick syrup, in which state it is run into shallow coolers, after which it is poured into vessels pierced below with holes which are stopped with plugs. After a time the syrup is stirred, whereby the crystallization of the sugar is promoted, and as soon as it has become solidified the plugs are removed. The uncrystallized liquid, still containing some cane sugar, with other matters, gradually flows away; and this, after a further boiling, is evaporated in order to obtain another crop of crystals—an operation which is sometimes repeated. The final refuse constitutes *molasses.*

The product thus obtained is called *raw* or *muscovado* sugar, and still contains certain impurities for the removal of which the process of *refining* is often resorted to.

Formerly the operation of *claying* was employed for the removal of the molasses from the sugar loaves, and which is thus performed:—When the syrup in the cones is properly granulated, which occurs in from 18 to 20 hours, the plugs are removed, and each is placed on an earthen pot to receive the drainings. After 24 hours the cones are placed over other empty pots. The claying now begins. It consists in applying to the smooth surface of the base of the inverted cone a moist layer of clay or tenacious loam. The water escapes from it by slow filtration, and descending through the body of the sugar carries along with it the molasses which still remain. This operation is repeated by the renewal of the clay a second, and even sometimes a third, time, until the sugar becomes white and clean. The sugar is then dried, crushed into powder, and sent to Europe. Clayed sugars are sorted into different shades of colour, according to the part of the cone from which they are obtained. Clayed sugar of Cuba, which is dried in the sun, is termed Havannah sugar. Claying is now but seldom resorted to in the British West India Islands, as it increases greatly the labour.

Treacle or *molasses* contains but little cane sugar, but a very large quantity of uncrystallizable sugar or glucose, which, since the fresh cane juice is almost entirely free from that description of sugar, has been derived entirely from the cane sugar, the transformation being aided especially by the heat employed in the evaporation and concentration of the juice. Since molasses is far less valuable than the crystallized cane sugar, it has at all times been the great object of the manufacturer to confine the conversion of the cane sugar to as narrow limits as possible, and various contrivances have been devised with this object. The greatest improvement of all in the manufacture of sugar was the invention of the *vacuum pan.*

From beet-root.—The roots are first pulped, the juice being separated either by pressure after the addition of 20 per cent. by weight of water, or by washing with cold water: or, lastly, by the rotatory action of a centrifugal machine, the cylinders containing the juice being perforated for its escape. The juice is heated to 68° C. by steam, which is conveyed through it by means of pipes; milk of lime is then added in the proportion of 12 lbs. of lime to 1,000 quarts of the juice, to neutralize and remove the various acids present. The mixture is now heated to the boiling point, when various impurities collect on the surface and are separated, as albumen, phosphate of lime, &c. The heating is known to be completed as soon as boiling juice below shows itself through the crust. The juice is now run off, a further quantity being obtained by subjecting the residue containing the impurities to pressure. Through the thin syrup thus obtained carbonic acid is passed to get rid of the lime, but a small portion still remains in combination with sugar. The carbonate of lime is separated by subsidence and decantation. The juice is now filtered through cloth bags, concentrated, and finally filtered through animal charcoal or bone-black, which removes colouring matter and also a further portion of the sugar-lime, and is then evaporated in open pans. The syrup, which has now acquired greater consistency, is again filtered through bone-black, and is evaporated *in vacuo* at a barometrical pressure of about 22″, till it becomes thick enough to draw out into granular threads, when after cooling and standing it yields crystals of cane sugar. The mother liquor, when further evaporated, yields second and even third crops of crystals; finally, nothing remains but molasses, as in the case of the sugar from the sugar-cane. The mixture of the successive crops of crystals constitutes raw beet sugar.

From the sugar maple.—The trees are tapped usually on the south face in the early spring obliquely from 18 to 20 inches above the ground, the holes being from 4 to 5 inches apart; they are made to a depth of half an inch into the alburnum or white bark. The juice is collected in troughs placed beneath, being conveyed to them by means of elder or sumach tubes which are inserted into the openings. The juice is boiled immediately after collection in order to anticipate fermentation. It is inspissated to the consistence of a syrup, is then strained through a sieve filter of woollen cloth, left to stand for some hours, is clarified with white of egg, boiled, the scum which forms on the surface removed, and the syrup evaporated till it is sufficiently concentrated to crystallize. This point is ascertained in the usual manner—namely, by placing a drop or two between the thumb and forefinger, and drawing it out into a thread, which should exhibit a granular aspect. It is then received into moulds, and after the molasses has drained off the sugar resembles brown cane sugar, its taste being equally sweet and agreeable. The manufacture of this description of sugar is yearly diminishing, in consequence of the rapid destruction of the American forests.

Preparation of glucose from potatoes.—The several kinds of sugar hitherto noticed are all cane sugars, and their preparation consists simply in their separation and purification, and there is no instance of the extraction of a sugar from any vegetable juice on a large and commercial scale belonging to the glucoses; formerly, however, this latter description of sugar was prepared in enormous quantities, chiefly from the potato, and was used either as a substitute for, or an adulterant of, cane sugar, at the time when the latter was much more costly than it is now.

The following is an outline of the process of making sugar from potato starch:—100 gallons of boiling water are mixed with 112 lbs. of the fecula and 2 lbs. of strong sulphuric acid. The mixture is boiled for about twelve hours. When all the starch is converted into sugar, the sulphuric acid is neutralized with chalk, the liquid filtered and evaporated to the density of about 1·300 at the boiling temperature, equal when cooled to 15·5° C. to 1·342. When the syrup is left at rest for some days it concretes in crystalline tufts, and forms an apparently dry solid of a specific gravity 1·39 to 1·40.

Potato sugar may be distinguished from pure cane sugar in the following manner:—Glucose sugars fuse at 105° C., whereas cane sugar melts only when heated to 137° C., and at this temperature it immediately becomes converted into caramel, whereas glucose is unaltered at a pretty high temperature.

The specific gravity of glucose is, as already noted, from 1·39 to 1·40, while that of cane and beet sugar is 1·606. At 1·343 the syrup of cane sugar contains 70 per cent. of sugar; at the same density syrup of starch sugar 75·5 per cent. when dried at 126·6° C., and freed from 10 per cent. of water, which it retains in the granular state, thus affording another distinction between the two sugars, but the best test of all is furnished by the copper solution.

THE REFINING OF SUGAR.

But by the various processes above described we have merely obtained the cane sugar in its raw or unrefined condition. We will next describe very briefly the processes whereby it is *refined*.

To obtain pure and colourless crystals the raw sugar is dissolved in about one-third of its weight of water, is mixed with a little milk of lime, heated to boiling, run off from the impurities which separate as a crust, filtered first through bags of thick twilled cotton-cloth, and afterwards, to remove the colour, through bone-black, the beds of which are sometimes no less than 50 feet thick, and evaporated in the vacuum pan. The liquor from the cotton filters has the colour of dark sherry, but as it issues from the charcoal filters it is perfectly clear and colourless.

The heat is now moderated, and to the highly concentrated syrup small quantities of unthickened juice are added, upon which sugar crystals immediately form. To impart the requisite hardness to the crystals heat is applied, and the crystalline mass put into the sugar moulds and left to drain, the formation of small crystals of uniform size being promoted by stirring and breaking up the crust which forms on the surface of the moulds. As soon as the crystallization is complete, the apex of the mould is opened to allow the syrup to drain off; the last portion of this, which still remains adhering to the crystals, is removed by pouring in some pure syrup, the drainage being sometimes hastened by the production of a vacuum.

Lastly, after desiccation, the formation of loaf or refined sugar is completed.

Formerly the serum of bullocks' blood was employed in the purification of the syrup, but we believe that this practice has long been discontinued.

Crushed sugar.—The process for the manufacture of what is known by the name of crushed sugar resembles that for loaf sugar, but the raw sugar employed is usually of an inferior quality. The filtration is less perfect and the process of liquoring is dispensed with where practicable. The first crystallization yields *crushed sugar*, and the second *pieces*, the drainage from which is known as *syrup*. This, when diluted, filtered through animal charcoal and concentrated, is called *golden syrup*.

Molasses.—Molasses is largely imported into this country, and since it contains much crystallizable sugar, it is purchased by refiners. According to Ure the treatment of molasses formerly was very simple. It was merely concentrated and allowed to stand in large moulds for several weeks to drain. The drainages were sold as treacle, and the impure, soft, and dark sugar formed what is called *bastards*, which is chiefly sold amongst the poorer classes. The more recent and improved plan is, after the dilution of the molasses, to filter through animal charcoal, concentrate to the crystallizing point, and transfer to the moulds. In this manner a bright yellow sugar and a very fair quality of syrup are obtained, in place of bastards and treacle. Good molasses should yield about 40 per cent. of sugar, 40 of syrup, and 20 per cent. of water and dirt.

THE PROPERTIES OF CANE SUGAR.

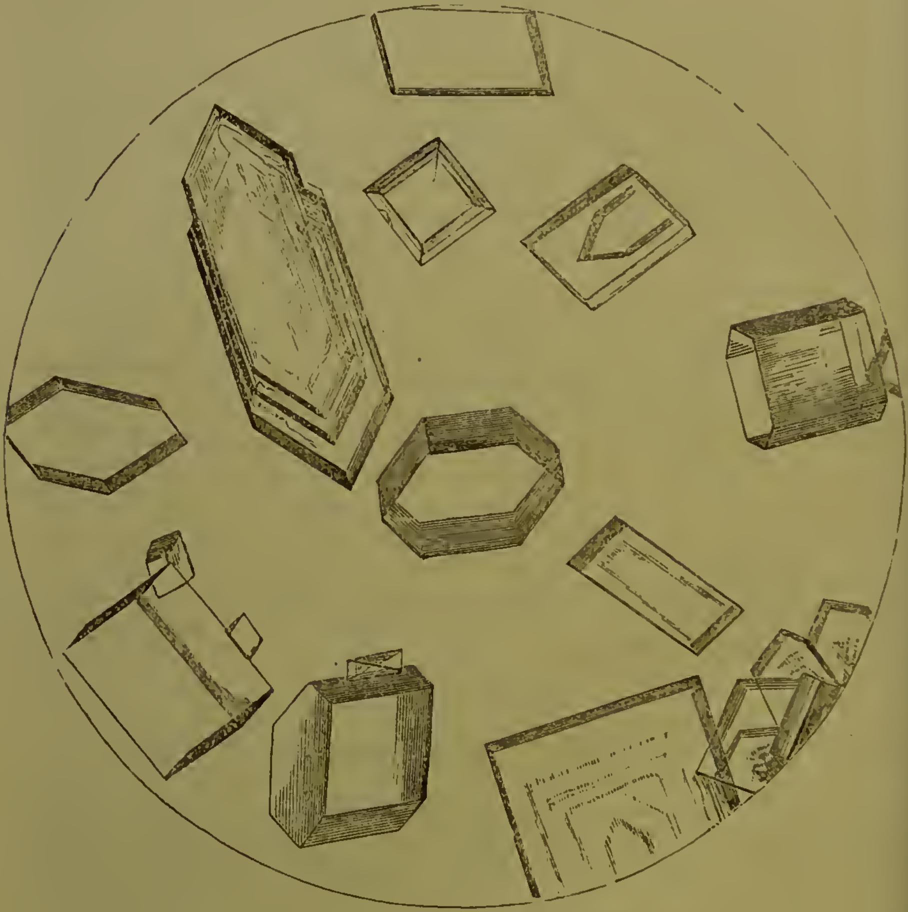
Sugar crystallises in the form of monoclinic prisms, usually with hemihedral faces (fig. 60). The crystals when broken become phosphorescent, and also when a strong electric discharge is passed through them. This phenomenon may be well seen by rubbing two lumps of sugar together in the dark, by powdering some sugar in a mortar, or by crushing some crystallized sugar-candy between the teeth in the dark.

The crystals have a specific gravity of 1·606.

Cane sugar is soluble in one-third of its weight in cold, and still more readily in hot, water. It is insoluble in ether and in cold absolute alcohol, while boiling alcohol dissolves about 1·25 per cent.; but should the alcohol contain water, it dissolves it much more freely. Its aqueous solution turns the plane of polarisation to the right.

It melts at 160° C. to a clear liquid, which solidifies into an amorphous mass, of which we have an exemplification in some forms of barley-sugar, acidulated drops, &c., which, however, after a while revert to the crystalline state. The confectioners usually add a small quantity of cream of tartar to the melted sugar, in order to destroy the tendency to crystallization.

Fig. 60.



Crystals of CANE SUGAR. 100 diameters.

The following table, showing the specific gravities of aqueous solutions of sugar, is abbreviated from the *Balling and Brix*:—

Table of the Specific Gravity of Solutions of Cane Sugar.

Percentage of Sugar.	Specific Gravity.	Percentage of Sugar.	Specific Gravity.
1	1·0035	20	1·0830
2	1·0070	25	1·1056
3	1·0106	30	1·1293
4	1·0143	35	1·1538
5	1·0179	40	1·1781
6	1·0215	45	1·2043
7	1·0254	50	1·2322
8	1·0291	55	1·2602
9	1·0328	60	1·2882
10	1·0367	65	1·3160
15	1·0600	70	1·3430

Decompositions.—When heated a little above 160° C., cane sugar is converted, without loss of weight, into a mixture of dextrose and lævulosan, $C_{12}H_{22}O_{11} = C_6H_{12}O_6 + C_6H_{10}O_5$, lævulosan being lævulose minus one molecule of water. At a higher temperature water is given off, the dextrose being probably converted into glucosan, which stands in the same relation to dextrose as lævulosan to lævulose. At about 210° C. a further quantity of water is given off, and *caramel* remains. At a still higher temperature the sugars are broken up; *carbonic oxide*, *carburetted hydrogen*, and *carbonic anhydride*, certain *brown oils*, *acetic acid*, *acetone*, and *aldehyde* are given off, while much charcoal remains behind. The oils contain a small quantity of *furfurol*, and a bitter substance termed *assamar*.

A few words may now be bestowed on some of the more important of the above substances. Thus *caramel*, when pure, is without taste, very soluble in water but insoluble in alcohol, its aqueous solution being of a rich brown tint. The method of obtaining it in a pure state is by first dissolving in a very small quantity of water, and precipitating by alcohol. It is unfermentable, and yields precipitates with ammoniacal acetate of lead and baryta water. It has been long regarded as a proximate principle, $C_{12}H_{19}O_9$, but it probably consists of a mixture of three closely-allied substances.

Acetone, C_3H_6O, is a colourless, very mobile liquid, possessing an agreeable odour and biting taste. It burns with a white flame, and has a specific gravity of 0·792 at 18° C. It is soluble in all proportions in water, alcohol, and ether, and is a solvent for camphor, fats, and resins. It is usually prepared by subjecting pure acetate of lime to dry distillation, when chemically pure acetone will be given off.

Aldehyde, C_2H_4O, is a mobile, colourless fluid, possessing a pungent suffocating odour. It is soluble in water, alcohol, and ether, and has a specific gravity of 0·800. It boils at 20·8° C. It is very inflammable, burning with a blue flame. It is prepared by distilling equal weights of alcohol, specific gravity 0·842, and bichromate of potash, with 1·3 part of oil of vitriol. Carbonic acid is evolved, and aldehyde collects in the receiver. Thus obtained it is not, however, pure. but must be subjected to a process of purification by means of ether and ammoniacal gas.

Furfurol, $C_5H_4O_2$, is a colourless oil, with a strong smell of cinnamon and bitter almonds. It has a specific gravity of 1·1648, and boils at 163° C. It is obtained by acting upon sugar, starch, bran, or sawdust, either by sulphuric acid alone, or with sulphuric acid and oxide of manganese.

Assamar is described by some as a yellow transparent solid, by others as a reddish-yellow syrupy liquid. It is extremely soluble in water, and attracts moisture from the air. It is neutral to test-paper, and reduces silver from its solutions.

We now return to the decompositions of cane sugar. When boiled for a long time with water, it takes up one molecule of water and yields inverted sugar, which is a mixture in equal atoms of dextrose and lævulose. This decomposition is very much accelerated by dilute acids, but small quantities of caramel are always formed.

Oil of vitriol chars cane sugar, even at ordinary temperatures, and thus it may be distinguished from the glucoses which are not so acted upon.

Saccharose, or cane sugar, easily takes up oxygen from salts of silver, mercury, and gold, reducing them to the state of metals. It prevents the precipitation of the oxides of copper, iron, and alumina from their solutions by caustic potash. When heated with sulphuric acid and oxide of manganese, formic acid is formed, while by the action of dilute nitric acid, saccharic and oxalic acids are produced. With very strong nitric acid it yields *nitro-saccharose*, a body resembling gun-cotton in composition.

Cane sugar does not, like the glucoses, assume a brown colour when heated with a solution of the alkalies; it combines with them, forming *sucrates*. When heated with caustic potash containing a little water, it yields formic, acetic, and propionic acids, while dry caustic potash decomposes it to oxalic acid. Subjected to distillation with soda-lime, ethylene, propylene, and amylene are given off.

Cane sugar does not yield directly under the influence of yeast alcohol and carbonic acid; it is first converted into a mixture of dextrose and lævulose, which then split up in accordance with the following formula:—$C_6H_{12}O_6 = 2CO_2 + 2C_2H_6O$.

Of all the varieties of sugar used in commerce there is none so important, in consequence of the vast extent of the manufacture, as that derived from the sugar-cane, the composition of which we shall now proceed to notice.

COMPOSITION OF THE SUGAR-CANE.

There are several varieties of the sugar-cane. The common variety, or Creole cane, grows between the Tropics, in every region, on a moist, light, rich, and well-manured soil. The Otaheitan variety is the quickest in growth and most productive in sugar, it yielding four crops in the same time that the Creole cane furnishes only three.

In some tropical regions the young shoots of the sugar-cane and the juice form an important and nutritious article of food. The ripe stalk of the plant is chewed and sucked, after being made soft by boring it; and enormous quantities are consumed in this way. 'Large shiploads,' states Johnston, 'of raw sugar-cane are daily brought to the markets of Manilla and Rio Janeiro; and it is plentiful in the markets of New Orleans. In the Sandwich and many other islands of the Pacific every child has a piece of sugar-cane in its mouth; while, in our own sugar colonies, the negroes become fat in crop time on the abundant juice of the ripening cane.'

The nutritive properties of the raw juice of the sugar-cane depend upon the circumstance that it contains, besides sugar, a considerable proportion of gluten.

According to Fownes, the *juice* has the following composition:—*Cane sugar*, a notable amount of *grape sugar* or *glucose*, *gum* and *dextrin*, *phosphates of lime* and *magnesia*, *some other salt of the same bases*, *sulphates* and *chlorides*, *potash* and *soda*; and, lastly, *a peculiar azotised matter* forming an insoluble compound with lime, not coagulable by heat or acids, and readily putrefiable. Of ordinary *vegetable albumen* there are but indistinct traces, and of *casein* or *legumin* none.

The following are some of the chief analyses of the *sugar-cane* which have hitherto been published:—

	Peligot and Dupuy.		Casaseca.			Avequin.	
						Ribbon Cane.	Tabiti Cane.
Water . . .	72·1	72·0	77·0	77·8	69·5	76·729	76·080
Sugar . . .	18·0	17·8	12·0	16·2	11·5	13·392	14·280
Gum, fat, resin and albuminous matters .	—	—	—	—	—	0·441	0·415
Woody fibre . .	9·9	9·8	11·0	6·0	19·0	9·071	8·867
Salts		0·4				0·368	0·358
	100·0	100·0	100·0	100·0	100·0	100·000	100·000

The sugar-cane, especially the violet variety, is coated with a peculiar kind of wax, termed *cerasine*, or sugar-cane wax.

The following are the more important analyses of *cane-juice* :—

	Avequin.	Peligot.	Playge.	Casaseca.
Sugar	15·784	20·90	20·8000	20·94
Various organic matters .	0·140	·023	0·8317	·012
Salts	0·236	·017	Small quantities	·014
Water	83·840	78·70	78·3325	78·80
	100·000	100·000	99·9642	100·000

The specific gravity of the juice varies no less than from 1·046 to 1·110, but usually from 1·070 to 1·090. When first expressed it is opaque, and of a yellowish-green colour. After boiling, a greenish scum rises to the surface, and the clear liquor is of a yellow colour. This scum, according to Avequin, consists of about 50 per cent. of wax, 10 per cent. of green matter, 22·7 of albumen and woody fibre, 3·3 of phosphate of lime, and 14·0 of silica. Pure juice contains about 81 per cent. of water, 18·20 of sugar, 0·46 of organic matter, and 0·35 of mineral matter.

The following table of analyses showing the composition of certain *raw sugars*, and of the products of a Greenock sugar-house, is by Dr. Wallace :—

	West India.	Beet.	Date.	Lumps.	Pieces.	Bastards.	Green Syrup.	Golden Syrup.	Molasses.	Treacle.
Cane sugar . .	94·4	95·7	95·4	97·3	87·7	68·3	62·7	39·6	48·0	32·5
Fruit sugar . .	2·2	0·3	1·8	0·5	6·0	15·0	8·0	33·0	18·0	37·2
Extractive and colouring matter . .	0·3	0·4	0·1	—	0·5	1·2	0·6	2·8	1·5	3·5
Ash	0·2	1·6	0·2	0·2	0·8	1·5	1·0	2·5	1·4	3·5
Insoluble matter .	0·1	—	1·7	—	—	—	—	—	—	—
Water . . .	2·8	2·0	0·8	2·0	5·0	14·0	27·7	22·7	31·1	23·4
	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0

The following analyses are by ourselves:—

	Raw Sugar.	Refined Sugar.	Refined Sugar.
Cane sugar	89·22	99·899	99·858
Glucose	3·69	none	none
Water	5·84	0·078	0·128
Suspended matter	0·12	none	none
Mineral matter	1·13	0·023	0·014
	100·00	100·000	100·000

The average composition of the *tuber* of the *sugar-beet* is as follows:—

Sugar	10·5
Gluten	3·0
Woody fibre, &c.	5·0
Water	81·5

But, of course, the proportion of sugar varies considerably in different cases. The average quantity actually extracted from beet is stated to be about 6 per cent.

According to Stenhouse, the *ash* of the *sugar-cane* has the composition given below:—

Silica	46·46	41·37	46·48	50·00
Phosphoric acid	8·23	4·59	8·16	6·56
Sulphuric acid	4·65	10·93	7·52	6·40
Lime	8·91	9·11	5·78	5·09
Magnesia	4·50	6·92	15·61	13·01
Potash	10·63	15·99	11·93	13·69
Soda	—	—	0·57	1·33
Chloride of potassium	7·41	8·96	—	—
Chloride of sodium	9·21	2·13	3·95	3·92
	100·00	100·00	100·00	100·00

The following analyses of the *ash* of *raw sugar* and *molasses* are by Dr. Richardson:—

	Sugar.	Molasses.
Potash	19·42	36·23
Lime	14·67	12·72
Magnesia	10·72	11·14
Oxide of iron	6·55	2·62
Oxide of copper	0·71	trace
Protoxide of manganese	trace	trace
Chloride of potassium	8·03	1·58
Chloride of sodium	15·46	25·87
Sulphuric acid	10·85	7·91
Silica	13·59	1·93
Ashes	1·33	3·60

Payen found 12 kilogrammes of *molasses* to contain:—

Sugar	7·56100
Acetate of potash	0·20930
Chloride of potassium	0·11460
Sulphate of potash	0·08550
Mucilaginous matter	0·07630
Phosphate of lime	0·05200
Nitrogenous substances	0·05000
Silica	0·02390
Acetate of lime	0·01620
Phosphate of copper	0·00020
Water	1·80000
Glucose and uncrystallizable sugar	1·56100

ON THE ANALYSIS OF SUGAR.

It will be unnecessary for practical purposes to make a full quantitative analysis of the sugars of commerce, but it will be sufficient to estimate the following:—*Water, glucose, cane sugar, mineral matter, matter insoluble in water* separating the amounts of *inorganic* and *organic matter*; the former will consist chiefly of *silica and other earthy matter,* and the latter of fragments of the *sugar cane, sporules* of *fungi* and *acari.*

The estimation of water.—2 or 3 grammes of the sugar are to be dried in a platinum basin in the water-bath until they cease to lose weight, the loss indicating the amount of water present.

Estimation of ash.—The dried sugar is then incinerated and the ash weighed.

Estimation of suspended matter.—20 grammes of the sugar are dissolved in water, and the solution filtered through a weighed filter. The filter is washed, dried, and weighed; thus the total amount of suspended matter is obtained. The filter is then burnt, and the residue, consisting of the silica and other mineral impurities, weighed. The difference between the two weighings gives the amount of the organic suspended matter.

Estimation of glucose.—The filtered solution of 5 grammes of sugar is made up to 500 cc., and the sugar estimated by means of the alkaline copper solution, to be presently described.

The principle of this method is the following:—Grape sugar is a body which easily takes up oxygen from other substances, it being converted into carbonic acid and water. Thus, acting upon a solution of nitrate of silver, metallic silver is thrown down; whilst from a solution of copper, not metallic copper, but a sub-oxide of copper, Cu_2O is deposited. This oxide being easily soluble, even in weak acids, it follows that this reduction can take place only in an alkaline solution. But by adding caustic soda or potash to a solution of sulphate of copper, the whole of the copper is precipitated as hydrate of oxide of copper. This precipitate, however, is easily soluble in tartaric acid and solutions of the alkaline tartrates. We have, therefore, in this property the means of preparing an alkaline copper solution without the employment of ammonia, in which the sub-oxide of copper is soluble.

The solution then is prepared as follows:—Perfectly pure crystallized sulphate of copper is powdered and pressed between blotting-paper to remove all adherent moisture. 34·639 grammes are exactly weighed out and dissolved in about 200 cc. of distilled water. In another vessel 173 grammes of pure tartrate of soda and potash are dissolved in 400 cc. of a solution of caustic soda, specific gravity 1·14. The copper solution is now slowly poured into the second solution, and the deep blue liquid thus obtained is diluted exactly to 1000 cc. 10 cc. of this solution contain 0·34639 gramme of sulphate of copper, and are capable of reducing 0·050 gramme of anhydrous grape sugar and 0·067 gramme of milk sugar. Starch, dextrin and cane sugar may be converted into grape sugar by prolonged boiling with dilute sulphuric acid. 10 cc. of the solution of copper correspond to 0·045 gramme of starch or dextrin, and to 0·0475 gramme of cane sugar.

The method of the employment of the copper test is as follows:—10 cc. of it are exactly measured and transferred into a small flask, 50 cc. of water are added, and the blue liquid is heated to boiling. The solution of sugar, which must not contain more than 1 in 100 parts of water, is now slowly dropped into the copper solution from a burette graduated into $\frac{1}{10}$ cc. The liquid assumes, after the addition of the first few drops, a greenish colour, and the sub-oxide subsides in proportion to the amount of solution added. The precipitate is first of a yellowish and then of a bright red colour. After further boiling the oxide readily settles, and the colour of the liquid can then be observed. As long as the faintest blue tint remains more sugar solution must be added. When the solution appears colourless a few drops are filtered into a test tube, and some sulphuretted hydrogen water is added to it after acidulation with hydrochloric acid. A black coloration would indicate the presence of copper and prove that the reaction is not yet finished; while, if it appears colourless, the volume of the sugar solution is noted. Suppose 10 cc. have been used, these contain 0·050 gramme of grape sugar.

It must be remembered that the separated suboxide of copper will gradually dissolve in the supernatant liquor as soon as this becomes cold, as oxide, into which it is converted by the oxygen of the atmosphere, and hence the necessity of conducting the process as quickly as possible.

Estimation of cane sugar.—Cane sugar, starch, and dextrin are, as mentioned above, converted into grape sugar by boiling with sulphuric acid. Two hours' boiling will be sufficient in the case of cane sugar, while starch and dextrin require from 3 to 4 hours. From 5 to 6 drops of sulphuric acid are amply sufficient for a gramme or two of the substance. This acid must, of course, after the conversion, be neutralized by the addition of a few drops of caustic soda; the copper solution is then to be employed exactly in the manner described under the previous heading.

Or the quantity of sugar may be estimated from the weight of the precipitated cuprous oxide. Dextrose, lævulose and the mixture of these, termed inverted sugar, all of which may be included under the head of glucose, reduce the same quantity of copper to the state of suboxide.

But the quantity may be determined in various other ways, as from the *carbonic anhydride or the alcohol* resulting from the decomposition of the sugar by fermentation. According to Pasteur, 100 parts of cane sugar yield 5·26 parts of water, 49·12 of carbonic acid, and 51·01 of absolute alcohol, the remainder of the sugar being transformed into glycerine and succinic acid.

A weighed quantity of the sugar, say 2 grammes, is dissolved in about 50 cc. of water, and a small quantity of dry or German yeast is added to it. The liquid is put into a small flask furnished with a cork perforated for the reception of a light tube filled with chloride of calcium. The whole apparatus is accurately weighed and kept for two or three days at a temperature of about 30° C., until the whole of the sugar has become decomposed. The apparatus is then again weighed, and from the loss of weight occasioned by the escape of the *carbonic* acid, the quantity of the sugar is calculated.

The liquid in the flask may be distilled, and the *alcohol* estimated in the usual manner by taking the specific gravity of the distillate.

In fruits, as has already been stated, cane sugar frequently occurs, together with glucose, when, should it be deemed necessary to separate the two kinds of sugar, this object may be effected by means of slaked lime, employed in the manner described on page 236.

Saccharimetry.—If a solution consist chiefly of cane sugar and water, as in cane and other saccharine juices and liquids, the quantity may be determined by taking the *specific gravity of the mixture* and consulting the table already given.

On the estimation of sugar by means of the polariscope.—Cane sugar, as we have seen above, turns the plane of polarisation to the right, and the angle of polarisation stands in direct proportion to the strength of the sugar solution. If we insert between two Nicol's prisms which cross each other at right angles, and do not therefore admit the passage of light, a stratum of a solution of sugar, the ray of light now passes through the prisms, and the analyser must be turned towards the left for a certain number of degrees until light is again excluded.

The sugar solution, before it can be analysed in this manner, must be subjected to special treatment. If the solution be turbid and contain gum, it should be mixed with one-tenth of its volume of a solution of isinglass; it should then be agitated with 1½ volumes of alcohol, whereby a precipitation occurs, the liquid becomes purified, and after filtration is ready for observation.

If the solution be coloured, it must be passed through animal charcoal; but as this substance is said to take up sugar, the first fourth that passes through must be rejected.

Should the solution contain one of the glucoses, as dextrose, lævulose, or inverted sugar, or any other substance possessing rotatory properties, and which are not altered by boiling with acids, the amount of cane sugar may be determined by noting the rotatory power of the solution both before and after conversion of the sugar by boiling with dilute sulphuric acid, the temperature being also observed in the latter case.

The first observation having been taken, 100 cc. of the solution are mixed with 10 cc. of strong hydrochloric acid, the mixture being heated for 15 minutes to 68° C. Now, since the rotatory power of the solution cooled to the original temperature, the observation having been made in a tube one-tenth longer than the first tube, remains unaltered so far as the glucoses are concerned; and whereas the cane sugar has now been replaced by inverted sugar, the amount of cane sugar may be calculated from the rotatory power peculiar to inverted sugar, as follows:—

The angle of rotation (a) of the original liquid is made up of the rotation of the grape sugar ($g\,G$), and that of the cane sugar ($c\,C$), whilst the rotatory power of the solution after conversion (a_1) depends upon the rotation produced by the grape sugar ($g\,G$) and that of the inverted sugar ($i\,C$). Therefore,

$$\begin{aligned} a &= g\,G + c\,C \\ a_1 &= g\,G + i\,C \\ a - a_1 &= c\,C - i\,C, \text{ or} \\ a - a_1 &= C(c - i). \end{aligned}$$

Therefore, $C = \frac{a - a_1}{c - i}$; a and a_1 are the angles obtained in the two experiments; c is at a temperature of 15° C. equal to 73·8°, and i equal to -25. Therefore $c - i = +98{\cdot}8$. From these data it is easy to calculate in each special case the quantity of cane sugar contained in 1 part of the sugar solution.

The specific rotatory power of the principal descriptions of sugar with which it is probable that we shall have to deal in connection with this subject are the following:—

Dextrose	+ 56°
Lævulose	−106° at 14° C.
"	− 53° at 90° C.
Cane sugar	+ 73·8°
Milk "	+ 59·3°
Inverted "	− 25° at 15° C.
Galactose	+ 83°

Separation of cane sugar from fruit sugar.—The juice, after the addition of some alcohol, should there be any fear of fermentation, is saturated with slaked lime and filtered. The filtrate is heated to the boiling point and again filtered at that temperature; the insoluble sugar-lime remaining on the filter, is thoroughly washed with water; transfer it to a suitable vessel, pour water upon it, and remove the lime from the sugar compound by means of a current of carbonic acid. The sugar solution is to be once more filtered, evaporated to a syrup, decolorized with animal charcoal, mixed with alcohol till it becomes turbid, and then left to crystallize. By the first operation not more than two-thirds of the cane sugar present are obtained, and the process must be repeated for the separation of a further quantity. Should the sugar solution be very turbid after the decomposition of the lime compound by carbonic acid, basic acetate of lead must be added, and then, after filtration, the excess of lead is removed by means of sulphuretted hydrogen.

The process of Peligot may be briefly noticed here. The cane sugar and glucose are combined with lime in the cold, and the lime estimated by neutralisation with sulphuric acid, and from the amount of this used the quantity of sugar, calculated as cane sugar, is ascertained. Another portion of the solution which has been saturated with lime is boiled, whereby the lime compound of cane sugar is precipitated, and the filtrate is again neutralised with sulphuric acid. The difference between the qualities of acid used before and after the boiling indicates the amount of cane sugar, while the volume of acid used for the second neutralisation gives the quantity of glucose.

The compound of lime with cane sugar has the formula $C_{12}H_{22}O_{11}$, 3CaO, while that with glucose is represented by $C_6H_{10}Ca_2O_6 + aq.$ The former contains 67·06 per cent. of cane sugar and the latter 65·22 per cent. of glucose.

A very simple process indicated by M. Payen in his work entitled 'Des Substances Alimentaires,' and employed in most sugar refineries in France, 'consists in washing the rough or moist sugar with alcohol at 85°, lightly acidulated with five hundredths of acetic acid, and saturated with sugar-candy. The liquid dissolves the sugar of starch and the uncrystallizable sugar, while it does not attack the crystals of cane or beet sugar.

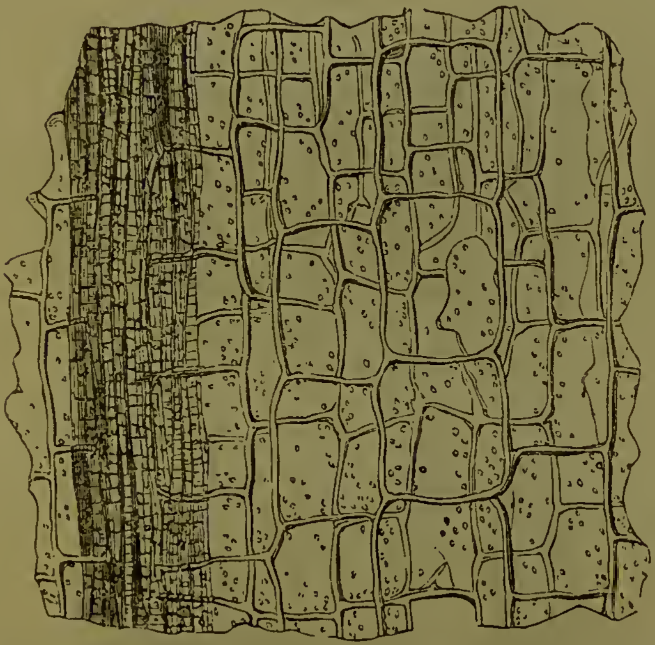
ON THE STRUCTURE OF THE SUGAR-CANE.

On the presence of fragments of sugar-cane in sugar.—The juice of the cane is expressed by means of powerful machinery, and during the operation numerous fragments of the cane itself, many of them of extreme minuteness, become detached, and pass into the juice. As this in its manufacture into sugar does not undergo in general any process of filtration, and as but few of the fragments drain away with the treacle, the greater number of them are retained in the sugar, in all unfiltered samples of which they may be readily detected in abundance by means of the microscope.

For the more ready and certain identification of these fragments, it is necessary to give a short outline of the structure of the sugar-cane itself.

The sugar-cane belongs to the class of Endogens, and consists of nearly cylindrical rods or stems, which are divided into joints at irregular distances of some three or four inches, and its structure is made up of cellular tissue, woody fibre, vessels, and epidermis.

Fig. 61.



A fragment of SUGAR-CANE, taken from near the centre of the stem, showing the size and character of the cells of which the parenchyma is formed, as well as, on the left, a bundle of woody fibre. Drawn with the Camera Lucida, and magnified 100 diameters.

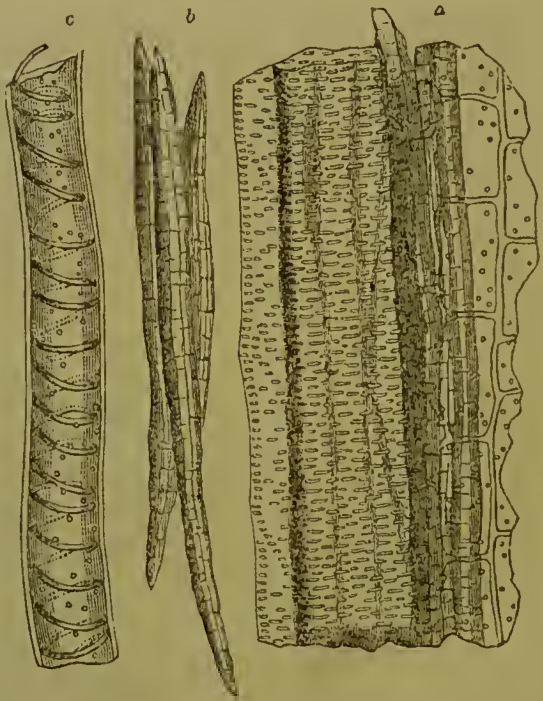
The parenchyma, or *cellular tissue*, forms the most considerable portion of the sugar-cane, and is constituted of aggregations of infinite numbers of utricles or cells, in the cavities of which the juice is enclosed.

These cells are usually rather longer than broad, and in the central parts of the bamboo they are several times larger than in its outer and harder part; the membranes of which the walls of the cells are formed are all finely dotted or punctated, a character by which the cells of the sugar-cane may be clearly distinguished from most other vegetable cells (fig. 61).

The *woody fibre* traverses the cane in a longitudinal direction in distinct bundles, which give to transverse sections a dotted appearance. Each bundle is constituted of a number of greatly elongated cells, and sometimes encloses vessels; these are also usually more or less dotted, like the ordinary cells of the parenchyma, of which, indeed, they are merely modifications (fig. 62).

The *vessels* follow the same disposition as the woody fibre in the centre of each bundle of which one or more is generally included. These vessels are of two kinds: the one is the interrupted spiral or dotted vessel, and the other the simple or continuous spiral vessel. The dotted vessels are sometimes cylindrical, but frequently polygonal, from the compression exerted upon them by the woody fibre, by which they are immediately surrounded, and the markings of the cells forming which they frequently exhibit on their surfaces: the spiral vessels are found chiefly in the outer and harder part of the

Fig. 62.

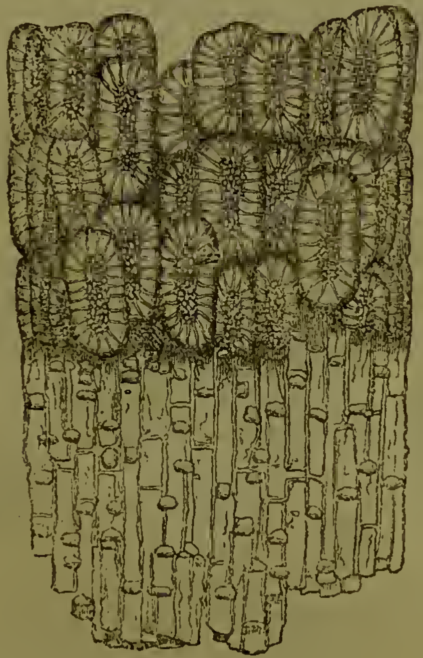


Fragments of the SUGAR-CANE, exhibiting the structure of the two kinds of vessels which enter into its composition, as well as the cells of which the woody fibre is constituted. *a*, *Dotted vessel* embedded in woody fibre; *b*, cells of *woody fibre*; *c*, *spiral vessel*. Drawn with the Camera Lucida, and magnified 200 diameters.

stem; they are formed of a single thread, remarkable for its thickness and strength (fig. 62.)

The *epidermis* or *cuticle* is known by the elongated, crenate cells of which it is composed, and the presence of stomata. At the distal extremity of each internode of the cane, the ordinary epidermic cells are replaced or overlaid by a layer of cells, having totally different characters; they are usually a little longer than broad, more or less rounded or oval in shape, marked with short and well-defined lines, disposed in a radiate manner: these cells resemble somewhat the cells found in the stones of fruit, and they form by their union a zone round the cane, polished, hard, and of about the third of an inch in depth (fig. 63).

Fig. 63.



A portion of the EPIDERMIS of the CANE, showing THE TWO KINDS OF CELLS of which it is composed—viz., those of which the general surface of the cane is formed, and those of which the polished zone described in the text is chiefly constituted. Drawn with the Camera Lucida, and magnified 200 diameters.

Fragments of sugar-cane are present in great quantity in Muscovado sugar, in the sugars of the shops in general, and in 'bastards,' a product of the manufacture of loaf sugar.

They are not contained in loaf sugar, crushed lump, sugar candy, nor in certain of the East Indian sugars; in the preparation of all these sugars the cane juice undergoes a process of filtration which effectually removes all solid and bulky impurities.

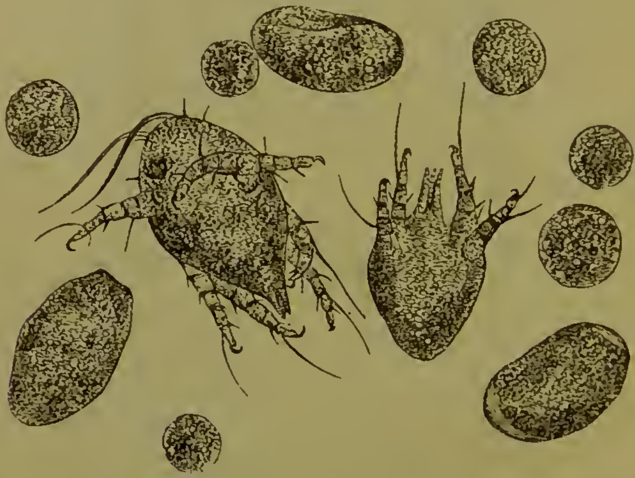
The presence of these fragments, in many cases, serves to distinguish satisfactorily cane sugar from either beet, maple, or grape sugar, a discrimination which otherwise it would be extremely difficult to effect.

By the same means, also, cane sugar may be detected when mixed with beet, a practice which, we believe, is not uncommon in France, and even in this country.

The saccharine juice of the beet-root is filtered, and therefore fragments of that plant are not present in the sugar made from it, as they would doubtless be were this means of purification not adopted.

The presence of sugar-cane in sugar lessens somewhat its sweetness, and thus helps to deteriorate both its quality and value.

Fig. 64.



Ova and young of the ACARUS SACCHARI, or *sugar insect.* Drawn with the Camera Lucida, and magnified 200 diameters.

PHYSIOLOGICAL ACTION AND PROPERTIES OF CANE SUGAR.

Sugar contributes to the formation of fat and lactic acid; it supplies material for the maintenance of respiration, furnishing by its oxidation heat to the system. Sugar, and treacle, especially the latter, have an aperient tendency.

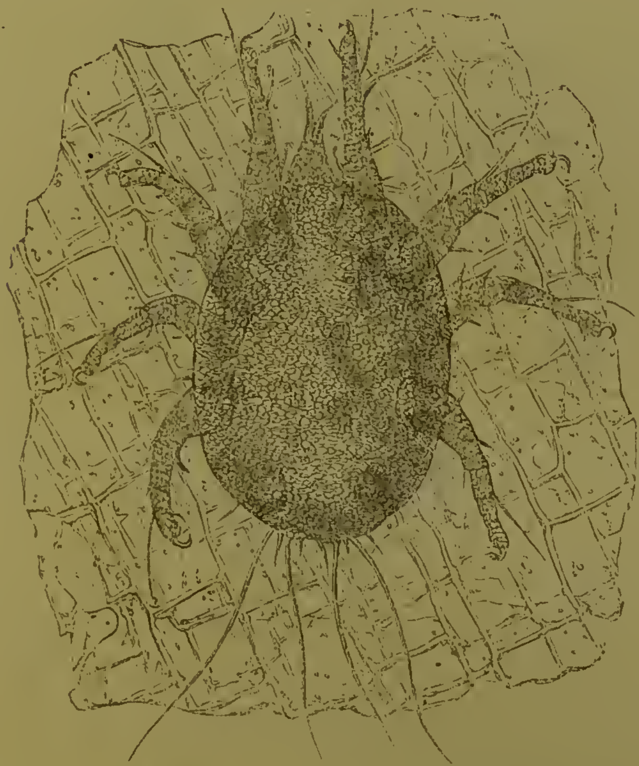
The Impurities of Unrefined or Brown Sugar.

Ordinary brown sugar, prepared from juice which has not been subjected to efficient filtration, contains almost invariably a great many fragments of the *tissue of the sugar-cane, sporules of a fungus,* numerous *acari, glucose,* and other impurities, from which white or refined sugar is entirely free.

The presence of these various and damaging impurities is thus explained.

The presence of the fragments of cane is accounted for by the cane-juice not having been filtered, of the fungus and of the insects, by the fermentation of the sugar, and the presence of nitrogenous matter. In sugars which have been filtered none of these impurities are met with. We shall now proceed to describe the fungus and acarus, or sugar-mite.

Fig. 65.



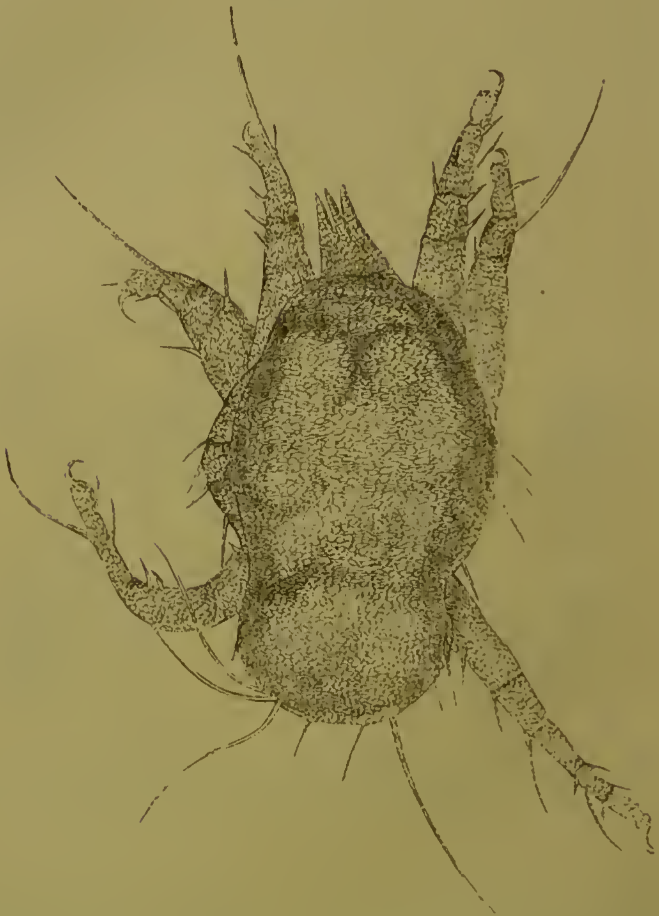
A Sugar Insect of medium size, representing its attitude and appearance when alive, and as seen crawling on a fragment of cane. Drawn with the Camera Lucida, and magnified 200 diameters.

On the fungus in sugar.—Innumerable sporules of fungi are very generally to be observed in the less pure kinds of sugar; they occur, indeed, most abundantly in those sugars which favour the development of the acari.

The sporules are best seen by dissolving a small quantity of any brown sugar in water, and looking for them in the sediment which subsides, and which, to a great extent, is constituted of the sporules in question.

These sporules are exceedingly minute bodies, usually of an oval form, as represented in fig. 67.

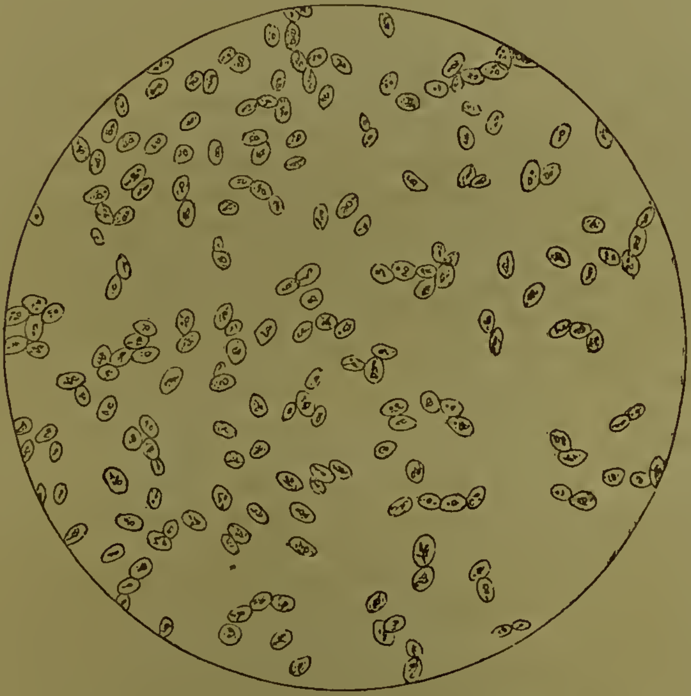
Fig. 66.



This figure represents a SUGAR INSECT, which has nearly attained its full development, and as it frequently appears when dead. Drawn with the Camera Lucida, and magnified 200 diameters.

The sugar-mite.—The sugar-mite, or *Acarus sacchari,* first detected by the author in raw sugar in 1851, and described in his report published in the *Lancet* in January of that year, is in size so considerable that it is plainly visible to the unaided sight. When present in sugar, it may always be detected by the following proceeding :—A teaspoonful or two of the sugar should be dissolved in a large wine-glass of tepid water, and the solution allowed to remain at rest for an hour or so; at the end of that time the acari will be found, some on the surface of the liquid, some adhering to the sides of the glass, and others at the bottom, mixed up with the copious and dark sediment, formed of fragments of cane, woody fibre, grit, dirt, and starch granules, which usually subsides on the solution of even a small quantity of sugar in water.

Fig. 67.



Sporules of the FUNGUS found in brown sugar. Drawn with the Camera Lucida, and magnified 420 diameters.

We will now proceed to give a description of the acarus in question, and observe, in the first place, that the whole of its development may be clearly traced out in almost every sample of brown sugar.

The *Acarus sacchari* is first visible as a rounded body, or egg; this gradually enlarges and becomes elongated and cylindrical until it is about twice as long as broad; after a time, from the sides, and one extremity of this ovum, the legs and proboscis begin to protrude. These stages of the development of the acarus are exhibited in fig. 64.

The acarus thus far formed goes on increasing in size until it attains its full growth, when it is visible to the naked eye as a mere speck.

In its perfect state, its structure is as follows:—The body is oval, or rather somewhat ovate, being broader behind than before; from its posterior part four long and stiff bristles proceed, two together on each side; and some eight or ten smaller ones are arranged nearly at equal distances around the circumference of the body; from its anterior part a proboscis of complex organisation proceeds, and from its inferior surface eight legs, jointed and furnished with spines or hairs at each articulation; the spine which issues from the last joint but one of each leg is very long, and extends much beyond the termination of the leg itself; lastly, each leg is armed at its extremity with a formidable hook.

Many of the above particulars are faithfully exhibited in the engravings, fig. 55 and 56.

In most samples of sugar the acari may be seen of all sizes, that is, in all the stages of their growth and in every condition; some alive, others dead; some entire, and others broken into fragments; bodies here, legs there.

We have said that the sugar-mite is very commonly present in the less pure sugars—we might have asserted that it is almost constantly so, the statement being based upon the examination of not less than *one hundred* different samples of sugar.

As a rule, the number of acari present in any sample of sugar may be taken as a fair indication of the purity of that sugar; the purer the sugar, the freer it will be from the sugar-mite.

Grocers' itch.—It is well known that grocers are subject to an affection of the skin, denominated 'grocers' itch,' of which one of the symptoms is extreme irritation and itching.

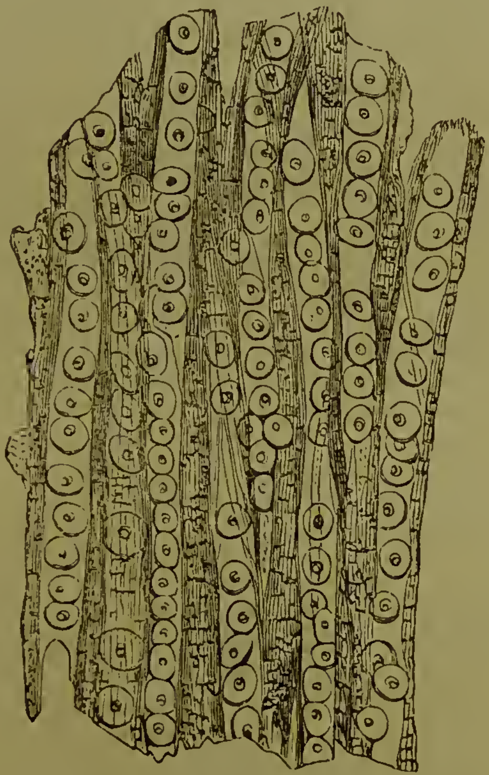
To this disease all grocers are not equally liable, but those more particularly who are engaged in the 'handling' of the sugars, as the warehousemen.

Now, the *Acarus sacchari* actually belongs to the same genus as the *Acarus scabiei*, or itch-insect, than which, however, it is larger, and possessed of an organisation still more formidable.

It thus becomes extremely probable that the disease in question does really arise from the sugar acarus—a point, however, which nothing short of microscopic observation can satisfactorily determine.

'As an article of food' (says Professor Cameron, who published in 1863 a most interesting pamphlet on the subject of the 'Sugar Insect') 'sugar unquestionably demands the careful consideration of every one. . . . In my capacity of public analyst for the city of Dublin, I have had occasion to examine, more or less minutely, nearly one hundred and fifty specimens of sugar, in quality varying from the purest white to the darkest brown. The greater number of these samples were perfectly genuine; some were of rather indifferent quality, and the rest, about fifteen, were so impure as to be quite unfit for use; they abounded in organic filth, and contained great numbers of disgusting insects. All the samples of inferior sugar were of the kind known as raw, and in no instance did I detect in the refined article the slightest trace of any substance injurious to the health or repugnant to the feelings. With such facts as these before me, and writing in the interest of the consumer, I advocate the exclusive use of refined sugar. I unhesitatingly assert that no one who pays any attention to the purity of his food, aware of the nature of the impurities so frequently abounding in the raw article, could, without a feeling of loathing, make use of it. . . . The use of raw sugar is rapidly on the decline, and I venture to hope that the publication of this little treatise will aid to utterly extinguish it. . . . Dr. Hassall, who was the first to notice the general occurrence of *acari* in the raw sugar sold in London, found them in a living state in no fewer than 69 out of 72 samples. He did not detect them in a single specimen of *refined*

Fig. 68.



A fragment of woody fibre of the Fir, showing its structure. Drawn with the Camera Lucida, and magnified 200 diameters.

sugar. The results of my examination of the sugar sold in Dublin coincided pretty closely with Dr. Hassall's experience. In the *refined* sorts I found nothing but crystallizable and non-crystallizable sugar and a little saline matter; in the *raw* kinds organic and mineral filth, often in great abundance. One of the samples which I examined contained a larger number of insects than I believe had previously been noticed, or at least recorded, by any other observer. In 10 grains weight I estimated no fewer than 500, most of which were so large as to be distinctly visible to the naked eye. It is no exaggeration to affirm that there cannot be less than 100,000 of these insects in every pound of *this* sugar. The assertion (as reported in the newspapers) that one pound of *raw* sugar contained 100,000 active insects must no doubt have appeared incredible to some people; but that I was not guilty of exaggerating the number was proved by the results of other observers. A committee of microscopists, composed of Drs. Aldridge, Minchin, Symes, and Booth, and Mr. Reynolds, visited the workhouse, and, in presence of the officials, examined the sugar, and satisfied themselves that my account of it was, in every respect, an accurate one. Two samples of the sugar were also examined, one by Dr. John Barker, Curator of the Royal College of Surgeons, Ireland; the other by Dr. Hassall, of London, a very eminent authority upon the subject. In 15 grains weight Dr. Hassall found considerably over 100 living insects, or at the rate of 42,000 per pound; and Dr. Barker estimated no fewer than 1,400 in 45 grains weight, or at the rate of 268,000 *acari* in each pound weight of sugar.'

Another impurity very frequently met with in lump sugar consists of *minute sawdust-like fragments*, not only of deal, but also of other woods; they often occur in great abundance, and of their presence it is not easy to give a satisfactory explanation. Possibly they are derived from the board on which the loaf sugar is broken into lumps.

The impurities of raw sugar prevail to such an extent, and are of such a nature—consisting of live animalculæ or acari, sporules of fungus, grit, woody fibre, &c.—that we feel compelled, however reluctantly, to come to the conclusion that *the brown sugars of commerce are, in general, in a state unfit for human consumption.*

We strongly urge the sugar refiner to prepare cheap forms of purified sugar, in powder, analogous to crushed lump; such sugars are extensively employed in Scotland, Bristol, and elsewhere, and are meeting with a large and ready sale.

RESULTS OF THE EXAMINATION OF SAMPLES.

Out of *seventy-two samples* of *brown sugar*, as procured at different shops, subjected to examination, *fragments of sugar-cane* were present in all but one. These were usually so small that they were visible only by the aid of the microscope.

Sporules and *filaments of fungus* were present in nearly all the sugars.

The acari were present in sixty-nine of the samples, and in many in very considerable quantities.

Grape sugar was detected in all the sugars.

Four of the sugars contained proportions of *starch* so considerable as to lead to the inference that they were adulterated.

Eleven other samples of brown sugar, as imported from the East and West Indies, furnished nearly similar results. Two only could be regarded as pure and fit for human consumption—a white, large-grained Calcutta sugar, resembling crushed lump; and a pale straw-coloured, large-grained, highly crystalline sugar from Cassipore. Both these sugars had no doubt been made from juice purified by filtration.

The results of the examination of *fifteen samples of lump sugar* were—

That in none of the sugars were fragments of cane present.

That in three of the sugars only were traces of grape sugar to be detected.

That in no case were acari observed.

That in none of the sugars were sporules and threads of fungi visible.

It has now been shown that the majority of brown sugars, although not adulterated, are yet, as imported into this country and as vended to the public, in an exceedingly impure condition.

THE ADULTERATIONS OF CANE SUGAR.

Various adulterations have been stated to be practised on sugar; as with *potato sugar, starch, gum* and *dextrin*, finely *powdered marble, chalk* or *whiting, sand, bone-dust*, and *common salt*.

Sugar being soluble in water, it is obvious that, were it to be adulterated with any insoluble substances, the discovery of such adulterations would be very easy and certain, for the only thing necessary would be to dissolve a portion of the sugar and to examine the precipitates which subsided.

We have examined several hundred samples of sugar, and the only insoluble substance, excluding accidental impurities, which we have met with, has been starch, which was present in small quantities in four samples. There is, therefore, but little foundation for the tales we hear about the presence of sand in sugar.

Formerly, however, when sugar was much dearer than at present, it used to be extensively adulterated with an inferior description of sugar made from potato starch by the action upon it of dilute sulphuric acid. But this adulteration has, we believe, ceased.

Dr. Letheby, in his evidence given some years since before the Parliamentary Committee of which Mr. Scholefield was the chairman, stated, in reply to a question put to him by Mr. Alderman Cubitt: 'Is there much potato sugar made?'—'A year or two ago ago, when there were diseased potatoes, there were tons made in a week at one establishment I visited. The disease in the potatoes did not touch the starch.'

'A few years ago,' writes Dr. Pereira, 'I inspected an extensive manufactory of sugar from potato starch at Stratford, in Essex; the sugar obtained was sold for the adulteration of brown sugar, and the molasses produced was consumed in an oxalic acid manufactory.'

There is a practice, termed the 'Mixing' or 'Handling' of sugar, which, although not an adulteration, may here be described. It consists in mixing together, in various proportions, sugar of different qualities and prices—as moist sugars with dry ones, very brown sugars with those of light colour—the resulting article presenting a tolerable appearance to the eye, but being rarely what it professes to be—real Jamaica or Demerara sugar.

In reference to this subject some remarks from the work of Dr. Scoffern on the manufacture of sugar may be quoted:—

'If the West Indian sugar-growers were to be furnished at once with a never-failing means of producing a large-grained, and therefore an easily cured, sugar, to the exclusion of all other sorts, their produce would have to encounter a difficulty which the consumer would scarcely imagine. Such large-grained sugars are very unfavourable to the perpetration of certain mysterious operations of legerdemain termed "handling," which grocers understand too well. They will not mix. A small-grained sugar may readily be incorporated with glucose, with pieces or bastards, and other less innocent bodies, without such incorporation being discoverable to the eye. A large-grained sugar, on the other hand, is a most refractory material for these little manipulations; its crystals, no matter how mingled with contaminating agents, never ceasing to manifest their native brilliancy, and thus proclaiming the fraud. It is most easy, then, to understand why the grocer, as a rule, does not encourage these large-grained sugars. He cannot "*handle*" them, and therefore brands them with a fault. He says they are deficient in saccharine matter—that they will not sweeten.'

THE DETECTION OF THE ADULTERATIONS OF SUGAR.

As we have seen, sugar, on the whole, is liable to but little adulteration, although the raw sugars of commerce contain many impurities. The chief adulterations which have been detected are those with *starch* and *starch sugar*. Other articles alleged to have been used for its adulteration are *gum*, *dextrin*, *chalk* or *whiting*, *gypsum*, *sand*, *bone-dust*, and *common salt*. These substances, except the gum and salt, are all insoluble in water; for their separation and identification nothing more in general would be necessary than to dissolve a portion of the sugar, to allow the precipitate to subside, and to examine it with the eye, and occasionally by chemical reagents.

If the sugar be adulterated with *gum* we must proceed as follows:—5 grammes of the sugar must be dissolved in boiling spirits of wine. The greater part of the gum will remain undissolved, and may be identified by its general characters; or the gum may be precipitated from its aqueous solution by means of acetate of lead, and estimated by evaporation and drying after the removal of the lead. *Dextrin*, which is intermediate in its characters between gum and starch, may be quantitatively estimated in the same manner as the gum; but it is not precipitated by acetate of lead, unless with the addition of ammonia; dextrin is further distinguished from gum by the purplish colour to which it gives rise when treated with a solution of iodine, as also by the circumstance that under the microscope the remnants of the starch corpuscles are still visible in many cases.

The presence of *farinaceous substances* may be thus ascertained. The precipitate obtained after the solution of the sugar in cold water should be treated with a little iodine; or, better still, it may be examined with the microscope, and the characters of the starch corpuscles determined. The quantity of starch present may be ascertained by collecting, drying, and weighing the residue, or by its conversion into glucose by means of dilute sulphuric acid in the manner described under 'Flour.'

Starch sugar is chemically identical with grape sugar; and since, as we have shown, this description of sugar is present to some extent in all the brown sugars of commerce, it is evident that the analysis necessary to enable the chemist to state whether the sugar is adulterated with starch sugar or not must be a quantitative one, and that he is only justified in concluding that a sugar is adulterated with that substance when the proportion discovered forms a considerable percentage of the whole article.

The process for the detection and estimation of this description of sugar will be found described under the head of 'The Analysis of Sugar.'

We now come to notice, generally and very briefly, the methods whereby the alleged *mineral* adulterations of sugar may be determined.

Carbonate of lime or *chalk* will be sufficiently discriminated by its insolubility in water and its effervescence on the addition of acids, but the full details of the process necessary for the exact identification and estimation of this substance will be found described in the article on 'Water.'

Sulphate of lime or *gypsum* may be estimated after its solution in hydrochloric acid by precipitating the sulphuric acid by means of chloride of barium and the lime by oxalate of ammonia, as elsewhere more fully described.

Bone earth or *phosphate of lime* is, of course, insoluble in water, and will collect at the bottom of the vessel. If now it be separated by filtration and treated with a little nitrate of silver, it will become of a bright yellow colour, or it may be estimated after its solution in nitric acid in the manner described in the articles on 'Tea' and 'Water.'

The method for the detection and estimation of *chloride of sodium* will also be found fully stated in the article on 'Water.'

Lastly, the *sand* is distinguished by its insolubility in mineral acids, and it may be readily dried and weighed.

CHAPTER IX.

COLOURED SUGAR CONFECTIONERY.

DEFINITION OF ADULTERATION.

Any foreign substances added for the sake of bulk, whether vegetable or mineral, such as plaster of Paris, chalk, starch, &c.; any poisonous or injurious colouring matter, whether mineral or vegetable, such as combinations of arsenic, antimony, copper, lead, mercury, iron, or aniline colours contaminated with arsenic.

The adulteration of articles of sugar confectionery is a subject of the very greatest importance in a sanitary point of view: that it must be so is evident when we consider the poisonous character of many of the substances used, and also the large consumption of these articles, especially by children and young persons.

That these articles are subject to gross and injurious adulteration has long been known, and the subject is particularly referred to even by Accum and other early writers on adulteration. Dr. O'Shaughnessy, in the preface to a paper on coloured sugar confectionery, published in the *Lancet*, in 1833, made these remarks:—

'In the following observations it is my principal aim to lay before the public and the medical profession a calm, dispassionate statement of the existence of various poisons (gamboge, lead, copper, mercury, and chromate of lead) in several articles of confectionery, the preparation of which, from their peculiar attractions to the younger branches of the community, has grown into a separate and most extensive branch of manufacture. I am fully aware of the hazardous task that individual undertakes who ventures in this country to signalise such abuses.'

THE ADULTERATIONS OF SUGAR CONFECTIONERY.

Of all the chief varieties of articles of sugar confectionery, we have subjected some hundreds to both microscopical and chemical examination, but we here give the results only of the analyses of 101 samples made some time back.

From an examination of this series of analyses, it appears:—

Of the yellows—

That *seven* were coloured with LEMON CHROME, or the pale variety of CHROMATE OF LEAD.

That *five* were coloured with ORANGE CHROME, or the deep variety of CHROMATE OF LEAD.

That *forty-seven* were coloured with the bright or canary-coloured variety of CHROMATE OF LEAD.

That *eleven* of the samples were coloured with GAMBOGE.

While the colour of the majority of the above samples was confined to the surface, in many other cases it was diffused equally throughout the whole mass of the sugar used.

Of the reds—

That *sixty-one* were coloured with *organic pink* colouring matters, consisting in most cases of *Coccus Cacti*, or *cochineal.*

That in *twelve* of the samples the colouring matter was RED LEAD, RED OXIDE OF LEAD, or MINIUM.

That in *six* cases the colouring ingredient consisted of VERMILION, CINNABAR, or BISULPHURET OF MERCURY.

Of the browns—

That *eight* were coloured with *brown ferruginous earths,* either *Vandyke brown, umber,* or *sienna.*

Of the purples—

That two samples were coloured with a mixture of *Antwerp blue,* which consists principally of Prussian blue, and an organic red pigment, most probably *cochineal.*

Of the blues—

That *one* was coloured with *indigo.*

That *eleven* were coloured with *Prussian blue,* or *ferrocyanide of iron.*

That *eleven* were coloured with *Antwerp blue,* which is a modification of *Prussian blue.*

That in *fifteen* samples the colouring matter consisted of GERMAN OR ARTIFICIAL ULTRAMARINE, which is a double silicate of alumina and soda with sulphuret of sodium.

Of the greens—

That *five* samples were coloured with the *pale variety* of BRUNSWICK GREEN.

That *four* were coloured with *middle* BRUNSWICK GREEN.

That *one* was coloured with the *deep variety* of BRUNSWICK GREEN.

These greens consist of a mixture, in different proportions, of the CHROMATES OF LEAD and *Prussian blue.*

That one sample was coloured with VERDITER OF CARBONATE OF COPPER.

That *nine* were coloured with SCHEELE'S GREEN, EMERALD GREEN, or ARSENITE OF COPPER.

That in *four* of the samples the colours used were painted on with WHITE LEAD OR CARBONATE OF LEAD. This was the case in all the cake ornaments.

It further appears from the above analyses—

That *thirteen* of the samples were adulterated with *hydrated sulphate of lime,* the quantity varying from 4·3 to 43·66 per cent.

That *twenty-one* of the samples were adulterated with different kinds of *flour,* in quantities varying from 1·66 to 25·56 per cent. In *seventeen* samples the farina consisted of *wheat flour;* in *three,* of *potato flour,* and in *one,* of *East India arrowroot.*

The above colours were variously combined in different cases; as many as three, four, five, six, and even seven colours occurring in the same parcel of confectionery, including three and even four poisons.

The following specimens are of this kind:—

Sugar seeds.—The colours of one sample of sugar seeds were *crimson, pale pink, light blue, dull greenish-blue, light grass-green, orange-yellow,* and *lemon-yellow,* intermixed with white globules. The colouring ingredients employed were: for the crimson and pink, the usual *non-metallic red*; for the blue, *Antwerp blue*; for the dull, greenish-blue, VERDITER, containing LEAD; for the grass-green, PALE BRUNSWICK GREEN; and for the orange and bright yellows, the orange and yellow CHROMATES OF LEAD, in large quantity. *Ash,* light reddish-brown, 1·06 per cent.; matter insoluble in water, chiefly *wheat flour,* 9·60 per cent.

Thus no less than *three active poisons* containing LEAD and COPPER were present in this sample in considerable amount.

Dog and hare.—The nose and ears of the dog, and the tongue of the hare, were coloured bright red with VERMILION. The body of the dog is spotted with large patches of GAMBOGE and *burnt umber,* as also was the figure of the hare which lay at its feet; while the green pigment on the base, of which there was a very large quantity, contained CHROMATE OF LEAD, and consisted of the pale variety of BRUNSWICK GREEN. *Ash,* dark reddish-brown, 2·0 per cent.

Mixed sugar ornaments.—The confectionery in this parcel is made up into a variety of forms and devices, as hats, jugs, baskets, and dishes of fruit and vegetables. One of the hats is coloured yellow with CHROMATE OF LEAD, and has a green hatband around it coloured with ARSENITE OF COPPER; a second hat is white, with a blue hatband, the pigment being *Prussian blue.* The baskets are coloured yellow with CHROMATE OF LEAD; into the colouring of the pears and peaches the usual *non-metallic red pigment,* CHROMATE OF LEAD, and MIDDLE BRUNSWICK GREEN, enter largely; while the carrots represented in a dish are coloured throughout with RED OXIDE OF LEAD, and the tops with the same green. This is one of the worst of all the samples of coloured sugar confectionery submitted to analysis, as it contains no less than *four deadly poisons.*

Twelfth-cake ornaments.—The ornaments in this parcel consisted of a ship in full sail, a duck, a fox, and a bunch of flowers, the principal colours being green, yellow, red, and brown; the chief pigments employed are CHROMATE OF LEAD, RED OXIDE OF LEAD or RED LEAD, VERMILION, *sienna*, and ARSENITE OF COPPER: these being present in poisonous quantity.

It will be observed that the list of colouring matters above enumerated includes some substances of an injurious character, and many which are amongst the most virulent and deadly of the mineral poisons. Of those which may be considered as more or less injurious are *ferrocyanide of iron* or *Prussian blue*, *Antwerp blue*, GAMBOGE, and *German* or *artificial ultramarine.* Amongst those which are deadly and poisonous, are—the three CHROME YELLOWS or CHROMATES OF LEAD; RED LEAD or RED OXIDE OF LEAD; WHITE LEAD or CARBONATE OF LEAD; VERMILION or BISULPHURET OF MERCURY; the three BRUNSWICK GREENS; VERDITER or CARBONATE OF COPPER; and EMERALD GREEN, SCHEELE'S GREEN, or ARSENITE OF COPPER.

Other articles which have been stated to be used in the colouring of sugar confectionery, and most of which we have ourselves detected, are *clay, chalk, Naples yellow, sulphuret of arsenic, massicot* or *oxide of lead, acetate* and *oxychloride of copper.*

It may be alleged by some that these substances are employed in quantities too inconsiderable to prove injurious; but this is certainly not so, for the quantity used, as is amply indicated in many cases by the eye alone, is often very large, and sufficient, as is proved by numberless recorded instances, to occasion disease, and even death. It should be remembered, too, that the preparations of lead, mercury, copper, and arsenic, are what are termed cumulative—that is, they are liable to accumulate in the system little by little, until at length the full effects of the poisons become manifested. Injurious consequences have been known to result from merely moistening wafers with the tongue; now, the ingredients used for colouring these include many that are employed in sugar confectionery: how much more injurious then must the consumption of sugar thus painted prove, when the pigments are actually received into the stomach!

That deadly poisons, like the above, should have been daily used for the mere sake of imparting colour to articles of such general consumption as sugar confectionery—articles consumed chiefly by children, who from their delicate organisation are much more susceptible than adults—is both surprising and lamentable. It is surprising, on the one hand, that the manufacturers of these articles should have been so reckless as to employ them; and, on the other, that the authorities should have tolerated their use.

Dr. Thomson furnished the Parliamentary Committee on Adulteration, in 1855, with the following particulars regarding the adulteration of sugar confectionery with *terra alba* or *sulphate of lime*:—

'I procured from a great manufactory of those substances specimens at different prices. There were about ten different samples, of which I have the details here; I will first speak of what are called mints, at *7d.* a pound; they contained 3·03 per cent. of a substance which is sold under the name of terra alba. This terra alba I found to be plaster of Paris. The second sample, at 84*s*. per cwt., contained 20·84 per cent. of terra alba. The third was caraways, at 5*d*. a pound, and contained 27·82 of terra alba. The fourth, another specimen of caraways, at 8*d*. a pound, contained 19·22 per cent. of terra alba. The sixth, almonds, at 10*d*. a pound, contained ·96 per cent. of terra alba. The seventh, another sample, at 8*d*. a pound, contained 7·02 per cent. of terra alba. The eighth sample, at 8*d*., contained 22·76 of terra alba. Raspberries, at 9*d*. a pound, contained 7·76 of terra alba. Strawberries, at 9*d*. a pound, contained 8·28 per cent. of terra alba.'

Mr. Gay states, in the course of his evidence before the above Committee :—

'I believe many articles of confectionery are adulterated; I think caraway comfits are very extensively adulterated, and also many of the peppermint lozenges. I believe the basis of both those and coriander and almond comfits are flour; after the seeds are put into the pan, a little syrup is thrown over them, and that is dusted over with either *flour* or *whiting*, or *plaster of Paris*; a pretty strong coat is put over them in this way, and then they are finished with a stronger and better syrup.

White lead used in sugar cake ornaments is itself often extensively adulterated with *sulphate of baryta*.

Flavouring with Essences.

Further, many articles of sugar confectionery are flavoured with 'essences,' which are often of an injurious and even dangerous character, some of them containing *prussic acid*, and many of them being prepared from *fusel oil*.

The most important of these are ethers, belonging to the monatomic series, as *acetate of ethyl*, C_2H_3O,C_2H_5O; *butyrate of ethyl*, C_4H_7O,C_2H_5O, or essence of pine-apples; a similar compound is formed with *methyl*, having the like odour of the pine-apple; *acetate of amyl* or essence of jargonelle pear, $C_2H_3O,C_5H_{11}O$; *valerianate of amyl* or apple oil, $C_5H_9O,C_5H_{11}O$. They are all prepared by distilling a mixture of the respective acids and alcohols with oil of vitriol.

In reference to the use of these essences, much information will be found in the evidence given before the Parliamentary Committee on Adulteration of 1855, already so frequently referred to.

'I have heard,' states Professor Taylor, 'that some of the Jargonelle pear drops and the ribstone pippin drops have produced drowsiness and stupour in children. It is an imposition on the public to sell in this way a chemically flavoured substance under another name.'

A very fragrant fruity essence may be produced from rotten cheese, by treatment with sulphuric acid and bichromate of potash.

Another essence extensively used for flavouring sweetmeats and confectionery is *ratafia*, *essential oil of almonds*, *essence of peach kernels* or *hydride of benzoyl*, C_7H_8O. It is obtained by distilling bitter almond cake with water, and it contains from six to twelve per cent. of *prussic* or *hydrocyanic acid*, CHN, but is most variable in its strength. As small a quantity as twenty drops has been known to occasion death.

There is another compound of prussic acid, called 'almond flavour;' it contains about one drachm of the essential oil to seven drachms of spirit, but its strength varies very much. Many fatal cases have resulted from the use of this flavouring substance.

The prussic acid in these preparations is not essential to their flavour, and might with a little care be readily separated, so that, as Professor Taylor remarks in his evidence before the Parliamentary Committee on Adulteration, 'there is no excuse for selling prussic acid in these compounds but laziness and ignorance.'

For further information respecting 'Artificial Fruit Essences,' the reader is referred to the article on 'Jams and Preserves.'

Poisonous papers used as wrappers of sugar confectionery.—Lastly, the *papers* in which the ornaments are wrapped are frequently coloured with various poisonous pigments—a practice which ought to be forbidden, since children are very apt to put these papers in their mouths and suck them.

In some other countries, as France, Belgium, and Switzerland, manufacturers of sugar confectionery have long been forbidden to use injurious colouring ingredients under severe penalties. Sellers of these articles in Paris are also obliged to put their names on every parcel of confectionery they sell; they are held responsible for all accidents which may arise from their consumption, and they are even forbidden to wrap the articles in coloured papers.

Following the example of the Council of Health of Paris, we now furnish two lists, one of colours the use of which may be permitted, and the other, of those colours the employment of which should be strictly prohibited, on the ground that they are all more or less dangerous to the public health, and most of them absolutely poisonous:—

List of Colours, the Use of which may be permitted.

YELLOWS.

Saffron.
Turmeric.
French berries.
Lake of ditto, or yellow lake.
Persian berries.
Lake of ditto.
Quercitron bark.
Lake of ditto.
Fustic wood.
Lake of ditto.

List of Colours, the Use of which should be prohibited.

YELLOWS.

Gamboge.
The three chrome yellows, or chromates of lead.
Massicot, or protoxide of lead.
Yellow orpiment, or sulphuret of arsenicum.
King's yellow, or sulphuret of arsenicum, with lime and sulphur.
Iodide of lead.
Sulphuret of antimony, or Naples yellow.
Yellow ochre.

List of Colours, the Use of which may be permitted.

REDS.

Cochineal.
Lakes of ditto.
Carmine and
Brazil wood.
Lakes of ditto.
Pink madder lake.

PURPLES.

Madder purple.
Logwood and indigo.
Any of the lakes, with indigo or litmus.

BLUES.

Indigo.
Litmus.

GREENS.

Sap green (juice of Rhamnus catharticus).
Yellow lake, or French berries, and indigo.

List of Colours, the Use of which should be prohibited.

REDS.

Red lead, minium, or red oxide of lead.
Vermilion, or bisulphuret of mercury.
Red orpiment, realgar, or bisulphuret of arsenic.
Iodide of mercury.
Red ferruginous earths, as Venetian red, &c.

BROWNS.

Vandyke brown.
Umber.

PURPLES.

All purples resulting from the mixture of any of the prohibited reds or blues.

BLUES.

Prussian blue, or ferrocyanide of iron
Indigo.
Antwerp blue, a preparation of Prussian blue.
Cobalt.
Smalt, a glass of cobalt.
Blue verditer, or sesquicarbonate of copper.
Ultramarine, a double silicate of alumina and soda, with sulphuret of sodium.
German or artificial ultramarine, which resembles in its composition natural ultramarine.

GREENS.

The three false Brunswick greens, being mixtures of the chromates of lead and indigo.
Mineral green, green verditer, or subcarbonate of copper.

List of Colours, the Use of which may be permitted.

GREENS.

Any of the vegetable yellows, or lakes, with indigo, including Persian berries and indigo.

Obs. — Of the above colours one, *sap green*, is certainly liable to injurious adulteration, and it is stated that *litmus* is so likewise.

List of Colours, the Use of which should be prohibited.

GREENS.

Verdigris, or diacetate of copper.
Emerald green, or arsenite of copper.
The true Brunswick greens, or oxychlorides of copper.
False verditer, or subsulphate of copper and chalk.

THE VARIOUS BRONZE POWDERS.

Gold, silver, and copper bronzes: these consist of alloys, in different proportions, of copper and zinc.
White lead, or carbonate of lead.

A great variety of colours are now prepared from *coal tar*, nearly every tint being imitated. Against the employment of these dyes, including the *aniline dyes*, there is little to be urged, provided they are pure. Unfortunately, however, they are frequently contaminated with *arsenic*, and hence their indiscriminate use is much to be condemned.

By an examination of these lists, it will be perceived that nearly all the substances formerly employed by the manufacturers of coloured sugar confectionery belonged to the second or prohibited list. Even the first list contains the names of two or three colours, the use of which is not wholly free from objection—as indigo, litmus, and sap green; the two latter in consequence of their liability to adulteration. Genuine litmus, being a vegetable colour, is of course harmless; but its use is rendered objectionable from its being frequently adulterated, according to M. Andral, with common *arsenic* and *peroxide of mercury*.

From ultramarine, in contact with an acid, sulphuretted hydrogen is freely liberated; and this liberation no doubt takes place readily in the stomach when any confectionery coloured by this pigment is partaken of: hence the use of this pigment is objectionable.

The danger of colouring articles of sugar confectionery arises, not merely from the wilful employment of substances of known hurtfulness, but also from their use through ignorance and accident. The excuse of ignorance may tell somewhat in favour of manufacturers who, in some cases, may not be aware of the deadly nature of the articles which they daily use, knowing them by their common or popular names.

The results recorded in these analyses are really of a very serious character, and we can well remember the time when the state of things we have here portrayed was even worse. Of late years, however, great improvement has taken place in the colouring of articles of sugar confectionery, and now it is by no means common to meet with verdigris or acetate of ocpper, with the verditers or carbonates of copper, or with mineral green or arsenate of copper, all of which are virulent poisons.

A few of the cases of poisoning resulting from the use of coloured sugar confectionery will be found recorded in 'Food and its Adulterations.'

THE DETECTION OF THE ADULTERATIONS OF SUGAR CONFECTIONERY.

We will now proceed to give some brief directions, which may prove of assistance to others who may desire to analyse for themselves any suspected samples of coloured confectionery. We shall, however, confine our directions chiefly to the detection of those substances which we have ourselves discovered in the different samples subjected to examination. From the large number of analyses which we have made, and the results of which we have already made known, the pigments detected will embrace certainly all the most important of those which are ordinarily employed in the coloration of confectionery.

Of the colours used, some are soluble in water, and others insoluble; the former include nearly all the vegetable colours, and the latter most of the mineral colours. In this particular, therefore, there is a broad distinction between vegetable and mineral colouring matters, which will be found very useful in guiding us in our subsequent operations.

In the majority of cases there is but one colouring matter present, and this is usually confined to the surface of the various articles of confectionery, while in other cases different colours are used in the same article. When the colour is confined to the surface, it is readily removed by washing in distilled water, from which, if mineral or insoluble, it will usually be precipitated after standing for some time, and it may then be obtained in an almost unmixed state, and weighed. When the colour is diffused throughout the whole of the article, the same end can be accomplished by dissolving it in water; the sugar will be removed by the water, and the colouring matter will subside. But should the article contain starch, or any other insoluble substance, it, of course, goes down with the colouring matter. When different colours occur in the same article, they must each be separately washed and tested.

In many cases a shorter method of proceeding than the above may be adopted. The confectionery, when it is supposed to be coloured with a fixed metallic salt, may be incinerated in a capsule, and the ash tested.

Nearly all the pigments used may be referred to one or other of the following colours: *red, yellow, blue, green, brown,* and *purple*; other tints occur, which are formed by various combinations of the primary colours.

Vegetable, Animal, and Mineral Reds.

If the *red* or *pink* colouring matter be of a *vegetable* nature, or indeed if it consist of *Coccus cacti* or *cochineal*, this may be ascertained by simply immersing a small portion of the coloured comfit or lozenge in a solution of caustic potash, and another piece in acetic acid; if it be a vegetable colour, or the animal colouring matter cochineal, it will become purplish in the alkaline, and brilliant red in the acid solution. If the colour be not thus affected, then there is reason to suppose that it is a mineral colouring matter, most probably either red lead or vermilion. Inasmuch as many red and pink comfits, &c., are coloured with non-metallic colouring matter, it is as well to try them all in this way in the first instance, and so save ourselves the trouble of analysing each for metallic pigments.

Mineral reds.—The *red oxide of lead* may be obtained either by washing or by incinerating the comfits.

If we desire simply to ascertain whether the red pigment consist of lead or not, we have only to treat it with a drop or so of nitric acid, and to add subsequently a little solution of sulphuretted hydrogen; these reagents may often be applied to the pigment upon the article of sugar confectionery, by which means we are enabled to ascertain in a minute or so whether the colouring matter consist of or contain lead or not. We may proceed in the same way to detect the lead in massicot, in the chromates of lead, either pure or when mixed with Prussian blue, as in the different Brunswick greens, only that in the case of the chromates and Brunswick greens it is best to use hydrochloric acid as a solvent for the lead.

We have stated that most of the mineral pigments may be procured in a separate state by washing out the sugar. Having in this case, by a preliminary trial, ascertained that the pigment we have to deal with consists of red lead, we have nothing more to do than to dry and weigh it in order to determine the quantity present.

But in some cases, owing to the use of starch, chalk, or other adulterating ingredient, it will not be possible to obtain the preparation of lead or other pigment in a separate state. We must then proceed as follows, to determine the amount of lead present:—

The lead must be precipitated from the solution of the ash, either as a sulphuret or as sulphate of lead; this must be collected, dried, weighed, and the lead calculated from it.

There is one source of fallacy which must be guarded against. If the sugar be adulterated with sulphate of lime, the lead may escape detection proceeding in this manner, in consequence of its being converted into a sulphate: in this case the soluble portion of the ash having been removed, the remainder should be fused with a mixture of nitre and bisulphate of potash; the residue, after having been well washed with water, is to be treated with a solution of ammoniacal tartrate of ammonia, by which means the sulphate of lead is taken up, and may be precipitated by means of sulphuretted hydrogen.

The *bisulphuret of mercury* or *vermilion*, after being obtained in as pure a state as possible by washing, must be dissolved in nitro-hydrochloric acid, and must be tested in the manner described in the article on 'Cayenne.' It is no uncommon thing to meet with, in the same red pigment, both lead and mercury, vermilion being very subject to adulteration with red lead.

Detection of the Yellow Colours.

The *yellows*, like the reds, may be either *vegetable* or *mineral*; but, contrary to what was found to be the case with the reds, the yellow colouring matters employed are for the most part mineral, consisting frequently of *lemons* or *orange-chromes*, both these being *chromates of lead*, and sometimes of either *Naples yellow* or *massicot.*

Mineral yellows.—All the yellows should therefore be tested for lead in the first instance. For this purpose the surface of the comfit should be touched with hydrochloric acid, which usually destroys the colour at once if it be a salt of lead, especially a chromate; afterwards a drop of a solution of sulphuretted hydrogen should be applied to the same spot as the acid, when, if lead be present, it will become more or less black according to the quantity. If the pigment contain lead, in all probability it is one of the chromates, and if not one of these, *massicot*, which consists of the protoxide of lead. The colour of *Naples yellow* is almost sufficient to distinguish it from the chromates of lead.

Naples yellow, or *sulphuret of antimony*, may be thus identified:—Dissolve the pigment in hydrochloric acid, add tartaric acid diluted with water, treat with sulphuretted hydrogen, when, if antimony is present, an orange-red precipitate will subside very different from that of sulphuret of arsenic.

Vegetable yellows.—Those articles which are not found to contain lead should be subsequently tested for *gamboge*, which is the next pigment most commonly employed; and if it do not prove to be this, then a portion of the comfit should be moistened with a solution of caustic potash, when, if it become decidedly browned, the colouring matter will be vegetable, and most likely *turmeric*, *saffron*, or *yellow lake*, which is usually formed from the colouring matter of French berries thrown down by alumina or lime, but it may be made from any vegetable yellow; these vegetable yellows were formerly not so frequently employed, on account of their liability to alter and fade on exposure to the air and light.

If the pigment be *gamboge*, it will form, with distilled water, a yellowish opaque emulsion, which will not let fall any deposit. This emulsion should be evaporated to dryness, and alcohol added to the residuum; the alcohol will take up the gamboge, and when water is added to the solution, the gamboge will be precipitated. If to the yellow precipitate a drop or two of strong ammonia be now added, it is redissolved, producing a blood-red solution, from which it is precipitated pale yellow by nitric acid. Turmeric gives nearly the same reactions, and therefore much care is requisite to discriminate between the two. Turmeric does not form so decided an emulsion with water as gamboge.

The Detection of the Blue Colours.

The *blues* may be also either *vegetable* or *mineral*; the former include *litmus* and *indigo*; and the latter, *Prussian blue*, *Antwerp blue*, the two *verditers*, which consist of *carbonate of copper*, the only difference between them being, that the paler verditer is diluted with lime; *cobalt*; *smalt*, which is a glass of cobalt powdered; and *artificial ultramarine*, which is made in imitation of true ultramarine or lazulite.

Vegetable blues.—The vegetable blue, *litmus*, is sufficiently distinguished by its becoming red on the addition of weak acids. This pigment is manufactured from several species of a lichen (*Rocella*), and, when genuine, is innocuous. In a Report of M. Andral, addressed some years since to the Prefect of Police, it is stated that some manufacturers mix common arsenic and peroxide of mercury with litmus, and M. Andral therefore considers that its use in the colouring of sweet confectionery should be prohibited.

Indigo is sufficiently distinguished by its subliming in dense violet vapours when heated, by forming a blue solution with concentrated sulphuric acid, and by its remaining unchanged in alkalies.

Mineral blues.—The colour of *ferrocyanide of iron*, or *Prussian blue*, is immediately discharged on the addition of the caustic alkalies, the iron being thrown down in the state of peroxide, when, if necessary, the iron may be collected and weighed; the colour is also destroyed by incineration, the red oxide of iron only being left, which may be weighed and calculated into Prussian blue.

Antwerp blue is Prussian blue, the colour of which is rendered lighter and brighter in consequence of its dilution with some colourless material, usually chalk. The tests for Antwerp blue are therefore the same as for Prussian blue, those for carbonate of *lime or chalk* being superadded. This and the preceding pigment is in general sufficiently distinguished by adding a drop or so of solution of ammonia or potash direct to them upon the sugar, these reagents at once destroying the blue colour.

The *verditers* are *carbonates of copper* distinguished from other salts of copper by the escape of carbonic acid on the addition of any mineral acid; when boiled for a long time, or heated carefully, the carbonic acid escapes, and the pigment becomes brown. The tests for copper, and the method by which it may be determined quantitatively, will be found described under the head of 'Pickles.'

The remaining blue pigments, *cobalt*, *smalt*, and *ultramarine*, are distinguished by their colour being fixed in the fire, so that the ash of sugar articles coloured with any of these substances is of a bright blue, the tint varying according to the blue used, as well as also in consequence of admixture with uncoloured substances, such as chalk, sulphate of lime, or pipeclay. These colours are somewhat expensive, especially the true ultramarine, but they are of such intensity that a little goes a great way; there is, however, a cheap kind of ultramarine, sold in the shops as *German* or *French ultramarine*, the price being about sixpence per ounce, and it is this blue pigment which is chiefly employed in the colouring of sugar confectionery. It consists of a double silicate of alumina and soda with sulphuret of sodium, and it may be distinguished, when free from admixture with other substances, by adding to it a little hydrochloric acid, and observing the odour of sulphuretted hydrogen evolved. This method of discrimination is, in the case of coloured sugar confectionery, for the most part inapplicable, since sulphuretted hydrogen is almost invariably thrown off whenever hydrochloric acid is added to the ash left on the incineration of most articles of sugar confectionery. The pigment ought therefore to be procured in a separate state, by washing, and the acid applied to it when dry.

The Detection of the Green Colours.

Vegetable greens.—Of the *greens*, there is but one *vegetable* green used—namely, *sap green*. This is prepared from the green berries of the buckthorn, *Rhamnus catharticus*; but its use is to be objected to on account of its frequent adulteration with green metallic pigments, containing either copper or arsenic, in order to heighten its colour and render it more permanent. It is bleached by chlorine and acids.

Metallic greens.—Of the *metallic greens*, some are simple colours, while others are composed of a blue and a yellow mixed. *The simple greens* are *acetate of copper* or *verdigris*, and *arsenite of copper, emerald green* or *Scheele's green.*

Acetate of copper is distinguished from other green salts of copper by the action of sulphuric acid; the acetic acid is liberated, and may be detected by its odour.

Arsenite of copper is best recognised by means of the arsenic, of which it is in part composed: a portion of the colouring matter separated from the sugar by washing, when perfectly dry, is placed in a test-tube open at both ends, the heat of a spirit-lamp being applied outside the tube; this will cause the arsenic to sublime, and, condensing on the cool side of the tube, it forms a white substance, which, examined with a low power of the microscope, is ascertained to consist of minute octahedral crystals of arsenious acid. This test is perfectly conclusive.

The *compound greens* ordinarily used are those commonly sold as *Brunswick greens*; they are the colours usually employed in making green paint, and are of three different tints, known as pale, middle, and deep Brunswick green. They consist of a mixture, in various proportions, of usually *Antwerp blue*, but sometimes *ultramarine*, and *chromate of lead*. When obtained in any quantity from the confectionery, and diffused through water in a shallow dish, the two colours easily separate, and may be distinguished by the eye alone.

They may usually be recognised, without the trouble of procuring them in a separate state by washing, by adding reagents direct to these pigments as they cover the sugar ornament. If ammonia or potash be added, the green colour disappears, and is replaced by a yellow; that of the Prussian blue being destroyed by the alkali, the chromate of lead comes into view again; if the pigment is touched with hydrochloric acid it becomes blue, this arising from the solution of the chromate of lead by the acid. These are ready and very satisfactory tests. Other compound greens are occasionally made by mixing a yellow pigment, usually *pale chrome*, with one or other of the verditers. The true Brunswick greens are *oxychlorides of copper*, but these, being very expensive, are seldom employed.

The *oxychlorides of copper* may be thus distinguished from the other green salts of copper. Dissolve the pigment in a little pure and dilute nitric acid, add nitrate of silver, when, if a white precipitate ensue, it consists of chloride of silver, which is soluble in ammonia.

The Detection of the Brown Colours.

They are distinguished by the iron contained in them.

The Detection of the Purple Colours.

The *purple colour* sometimes met with in sugar confectionery is usually composed of a mixture of *Antwerp blue* and some *vegetable pink*, as *rose-pink*, the *lakes*, or *cochineal*. We must therefore test for the pigments named by the methods already indicated.

The Detection of Bronze Powders.

Bronze powders consist of an alloy of copper and zinc: usually they are sufficiently distinguished by their metallic appearance; in doubtful cases they may be dissolved by means of nitric acid, the excess of acid got rid of by evaporation, and the aqueous solution tested for copper and zinc; the solution should be separated into two equal portions: the one tested for copper in the usual manner, from the other the copper should be removed by means of sulphuretted hydrogen, and the filtrate tested for zinc as described under 'Vinegar.'

The Detection of Chalk, Plaster of Paris, and Clay.

Having completed the description of the methods by which the numerous pigments employed to colour sugar confectionery may be detected, it now remains only to indicate the processes by which the other substances, not pigments, either ascertained to be used by ourselves or others in the adulteration of sugar confectionery, may be discovered.

The principal of these substances are various kinds of *starch*, *chalk*, *hydrated sulphate of lime*, and *white potters' clay*, *pipe clay*, or *Cornish clay*.

Ordinary *plaster of Paris*, although stated to be employed in the manufacture of confectionery intended to be eaten, can scarcely ever be so, since when this is moistened with water it quickly becomes solid, retaining its solid state after incineration; on the other hand, hydrated sulphate of lime does not remain solid, and when exposed to a red heat it is still a powder. The processes for the qualitative and quantitative determination of this and the following salt are described in the article on 'Tea.'

Chalk is sufficiently identified by its appearance, by its effervescing on the addition of an acid, and by the lime thrown down from its solution by oxalate of ammonia. Alumina is detected by the process indicated under the head of 'Bread.'

The Detection of the Different Kinds of Starch.

The kind of *starch* employed is detected by means of the microscope. A minute portion of the sugar should be placed upon a slip of glass, and a drop of water added; if the sugar dissolve without any appearance of residue, the solution being quite transparent, the probability is that no starch is present, but if there be any residue, this should be placed under the microscope, when the starch, if present, will usually be recognised by the form of the granules, but should the starch be in an amorphous state in consequence of its having been boiled, then a little iodine should be added to the residue, which will at once reveal its presence. The quantity may be estimated in either of the following ways:—When starch only is mixed with the sugar, the latter may be dissolved out, and the starch collected, dried, and weighed; after drying and weighing, incineration must be resorted to, and the amount of starch estimated from the loss of weight; but when any other insoluble substance besides the starch is present, the starch may be converted into glucose with sulphuric acid, as described under 'Flour.'

CHAPTER X.

HONEY AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Added water and any foreign vegetable substance, including cane sugar and glucose or any mineral substance.

HONEY consists of the saccharine exudation from the nectaries of flowers collected by bees, and modified and elaborated by them in the crop or honey bag, which is an expansion of the œsophagus, and from which it is discharged on their return to the hive, and deposited in the various cells of the comb.

It consists of *lævulose* and *dextrose*, forming *inverted sugar* with an excess of *dextrose, cane sugar*, *gum*, *extractive*, a little *wax*, some *vegetable acid*, and much *pollen*, together with certain *odoriferous principles* derived for the most part from the plants from which the honey is gathered.

The pollen in honey is essential to the nourishment of the bees themselves, since it is the only source of the nitrogen obtainable by them in the winter.

The following are the results of the analyses recently made by us of four samples of honey :—

	I.	II.	III.	IV.
Water	17·48	19·56	16·88	13.63
Cane sugar	none	0·94	1·82	5·29
Glucoses	82·50	79·48	81·00	81·04
Insoluble matter	trace	trace	trace	trace
Mineral matter	0·02	0·02	0·30	0·04
	100·00	100·00	100·00	100·00

These honeys were not taken from the comb, and appear to represent only the liquid and uncrystallised portion.

Honey is usually divisible into two parts, one liquid and the other solid and crystalline, the latter consisting in part of cane sugar, and partly of granular masses formed of needlelike crystals of dextrose. The proportion of solid sugar is the greatest in old honey, but the quantity of cane sugar is largest in new honey, since it becomes gradually converted by keeping into inverted sugar. The honey furnished by a species of wasp, *Polybia apicipennis*, found in Central America, yields cane sugar in large crystals, according to Carsten ; but there is nothing singular in this fact, since that furnished by the honey-bee very commonly contains, as represented by the author many years since, well-defined crystals having the form of cane sugar, and which are well shown in figures 69 and 70.

The fluid portion contains, besides lævulose, inverted sugar and some cane sugar, the colouring and the odoriferous substances of the honey. The honey which flows spontaneously out of the comb on the application of a gentle heat consists mostly of the fluid portion, and is called virgin honey, while ordinary honey is procured both by pressure and heat. The first honey collected by bees is also sometimes called virgin honey. This description of honey is considered the best, is of a pale colour, granular texture, and possesses a fragrant smell, while the common honey obtained from the older cells is darker coloured, thicker, and does not possess so agreeable a smell.

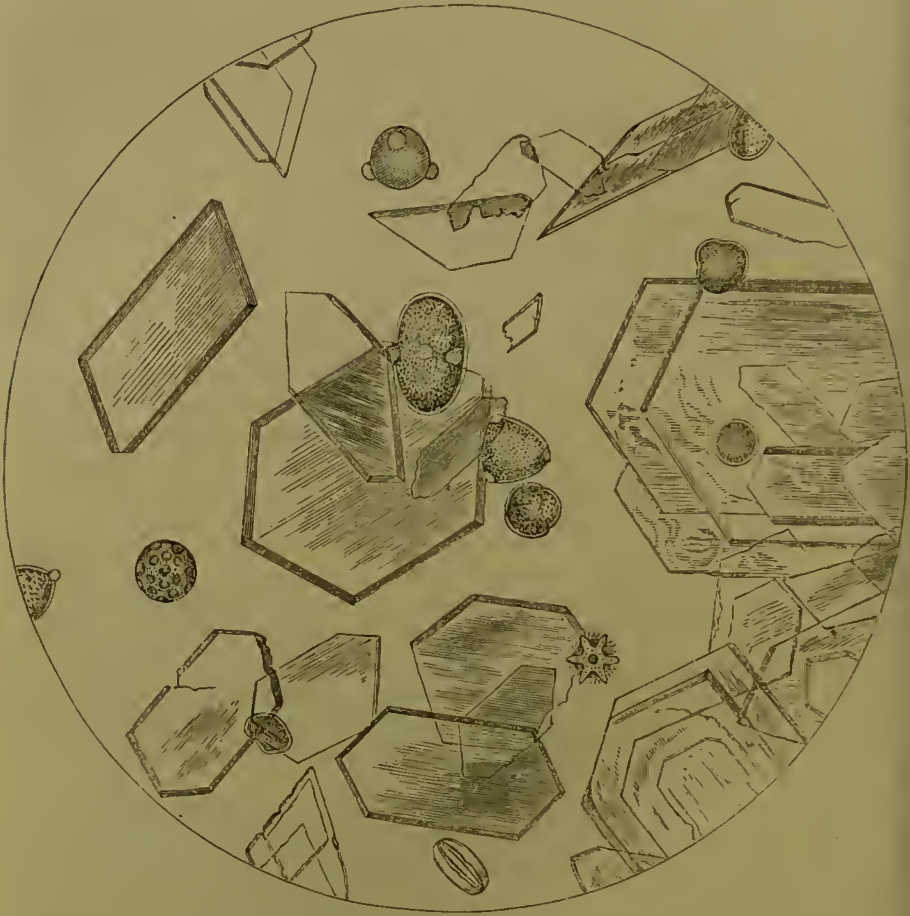
By pressure in a linen bag the fluid and liquid portions may be separated from each other, a clear syrupy substance passing through the linen, and the white solid sugar remaining behind.

To the various foreign substances contained in it, including especially pollen, the different colours, flavours, and odours possessed by the honey of different countries and districts are owing, and the possession of which, in some cases, causes it to be so highly prized. 'Hence the estimation in which the honey of Mount Ida, in Crete, has been always held. Hence also the perfume of Narbonne honey, of the honey of Chamouny, and of our own high moorland honey, when the heather is in the bloom. Sometimes these foreign substances possess narcotic or other dangerous qualities, as is the case with the Trebizond honey, which causes headache, vomiting, and even a kind of intoxication, in those who eat it. This quality is derived from the flowers of a species of rhododendron, *Azalea pontica,* from which the honey is partly extracted. It was probably this kind of honey which poisoned the soldiers of Xenophon, as described by him in the Retreat of the Ten Thousand.'—*Johnston.*

The following is Xenophon's description :—'And there were there, in a village near Trebizond, a number of bee-hives, and as many of the soldiers as ate of the honey-comb became senseless, and were seized with vomiting and diarrhœa, and not one of them could stand erect. Those who had swallowed but little looked very like drunk men, those who ate much were like mad men, and some lay as if they were dying. And thus they lay in such numbers as on a field of battle after a defeat. And the consternation was great. Yet no one was found to have died; all recovered their senses about the same hour on the following day. And on the third or fourth day thereafter, they rose up as if they had suffered from the drinking of poison.'

The solid part of honey, examined under the microscope, is seen to consist of myriads of regularly-formed crystals; these crystals are for the most part exceedingly thin and transparent, very brittle, so that many of them are broken and imperfect; but when entire they consist of six-sided prisms, apparently identical in form with those of cane sugar. We see no other conclusions to come to however, but that they really represent the crystals of dextrose, seeing that they occur in

Fig. 69.

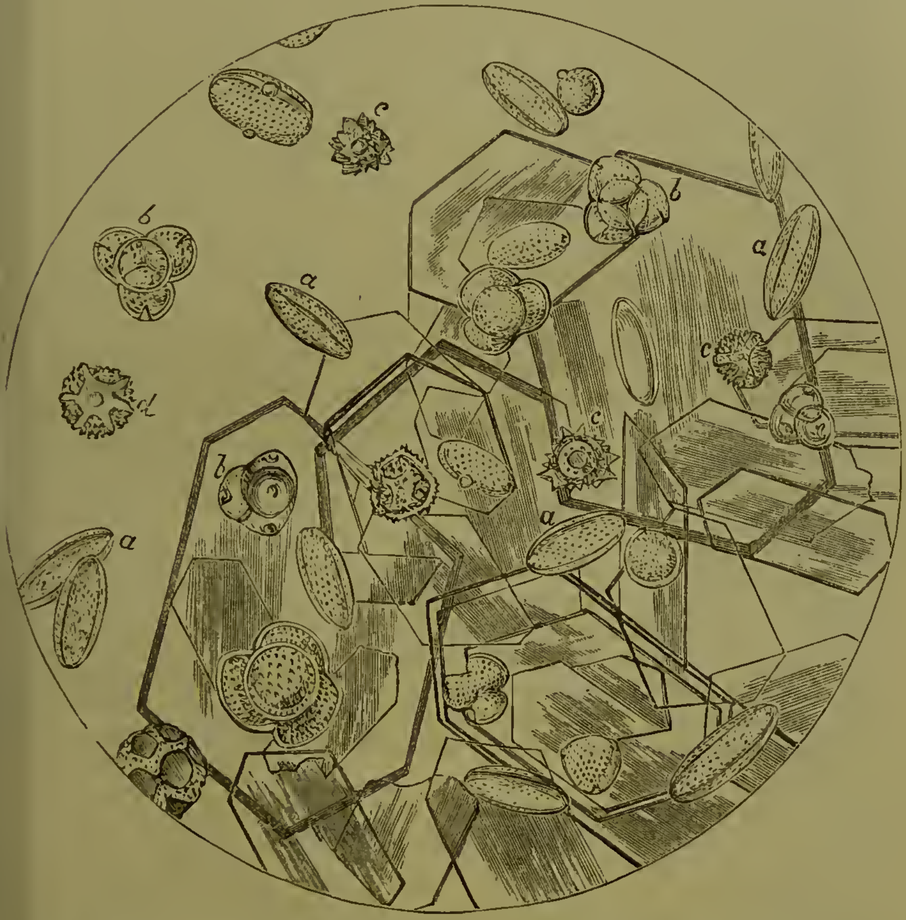


Crystals of HONEY, intermixed with the pollen granules of the flowers from which the Honey was gathered. Magnified 225 diameters.

honeys from which cane sugar is absent or nearly so. These crystals are, so far as our observations go, always present in honey, and they are usually the only kind met with.

Intermingled with the crystals may also be seen pollen granules of different forms, sizes, and structure; these are in such perfect condition, that in many cases they may be referred to the plants from which the honey has been procured. This is a very interesting and beautiful fact in relation to honey. The bees, in collecting the honey from the flowers, carry away with them also some of the pollen of those flowers; now this pollen consists of complex utricles or cells, differing in size, shape, and organisation in different orders of plants,

Fig. 70.



Honey collected principally from a Heath, as shown by the presence of numerous pollen granules of the *furze* and of *heath*; *a*, *a*, pollen granules of furze; *b*, *b*, ditto of heath; *c*, *c*, ditto of some composite flower. The other granules present we have not identified.

and in different plants, so that the observer acquainted with the characters of the pollen of flowering plants will be enabled in many cases to determine whether any particular honey submitted to his examination was collected from flowers of foreign or native growth, whether from those of the field, the garden, the heath, or the mountain.

It has occurred to the author to make another highly interesting observation in connection with honey, showing in a very striking manner the amazing industry manifested by bees in the collection of honey. In examining the blossoms of our native heaths, now unfortunately many years since, and long before the first edition of 'Adulterations Detected' was published, we were surprised to observe that there was scarcely one that had arrived at maturity that did not exhibit, usually on the upper surface of the corolla, one or more dark spots, occasioned by perforations. The conjecture at once occurred to us, that these perforations were made by the bees in their search for honey, and in order to facilitate its abstraction from the tubular-shaped flowers. It was not long before the correctness of this conjecture was ascertained. The bees, on alighting on the flowers, almost constantly inserted their probosces either through one of the apertures already made, or they pierced a fresh one. Now, of the countless myriads of blossoms in some miles of heath, there was scarcely one mature one observed by us which had not been perforated.

A very good way of obtaining the pollen of honey for microscopical examination is to dissolve a teaspoonful or so of the honey in cold water contained in a conical glass, and to examine a little of the sediment which subsides in the course of a few minutes, and which in some honeys is very considerable. The water causes the forms of the granules to change in some cases, and hence a better plan is to view the pollen as contained in the fluid part of the honey.

Some of the earlier numbers of the 'Annals of Natural History' contain an article by the author, illustrated by a large number of figures, on the structure of the pollen granule; this will be found of some assistance to those who may desire to identify the pollen found in honey. Another useful plan of proceeding is to collect and examine the honey of the flowers from which the bees are supposed to have collected the honey, and then to search in this for the corresponding pollen granules.

THE ANALYSIS OF HONEY.

No reliable analyses of honey have yet been made, so far as we are aware, if we except the four samples the results of the examination of which have already been given.

The only determinations which are practically required are those of *water*, *cane sugar*, *glucose*, and *insoluble matter*, consisting chiefly of the *pollen* and the *ash*.

The methods to be pursued in the determination of the cane and other sugars have been fully described in the article on 'Sugar,' and need not here be repeated. There is, of course, no difficulty in estimating the matter insoluble in water and the ash. Since the composition of the glucoses is altered at a low temperature and they soon lose water, it is safest to estimate the amount of moisture present by difference.

BEES' WAX.

In connection with the subject of honey it will be of interest and utility to make a few observations on another product of the bees—namely, bees' wax.

It was first demonstrated by the experiments of John Hunter and M. Huber that wax is the product of the secretion of a special organ situated on the sides of the abdomen of the bee. 'On raising the lower segments of the abdomen these sacs may be observed, as also scales or spangles of wax arranged in pairs upon each segment. There are none, however, under the rings of the males and the queen. Each individual has only eight wax sacs or pouches, for the first and the last ring are not provided with them. H. Huber satisfied himself by precise experiments that bees, though fed with honey or sugar alone, produce, nevertheless, a very considerable quantity of wax, thus proving that they were not mere collectors of this substance from the vegetable kingdom.'—*Ure.*

Wax is met with very commonly in the vegetable kingdom. It is contained in the pollen of most flowers, in the fæcula of many plants, as the cabbage, and it forms a varnish on the upper surface of the leaves of many trees. It has been observed especially in the juice of the *cow tree*, while the berries of several species of *Myricæ* afford much wax.

Some of the principal varieties of wax met with are the *Carnauba wax* of Brazil, the produce of *Copernicia cerifera*; *cork wax*, or *cerin*; *pine wax* or *ceropic acid*; *sugar-cane wax* or *cerosin*; *myrtle wax* or *myrica tallow*; *ocuba wax* and *palm wax*; *Chinese wax* or *pela*, called vegetable insect wax, because it is produced by the puncture of a species of coccus; *cow-tree wax*, *Cuba wax*; *Japan wax*, from the root of the *Rhus succedanea*; and, lastly, *propolis* or stop wax, used by bees to mend the cracks in their combs.

Bees' wax in its unpurified condition is of a yellow colour and has the smell of honey, the colour and smell both being derived from the honey itself, since those cells in which honey has not been deposited are white and scentless.

Wax is freed from its impurities by melting it in hot water or steam, allowing the impurities to subside, running off the clear supernatant oily liquid into oblong troughs furnished with a series of holes at the bottom, through which the liquid runs out, falling upon wooden cylinders which revolve, being partially immersed in cold water. The ribbons thus obtained are spread out upon canvas, and then bleached by exposure to the air and sun, being frequently turned over and watered from time to time. In order to obtain wax of the greatest purity and whiteness, it is necessary that the various operations be repeated several times. In France, cream of tartar and alum are employed in the purification of wax.

The wax when bleached is melted, strained through silk sieves, and moulded into thin disk-like pieces, weighing from two to three ounces each. Thus purified it is white and transparent, without taste or smell. It has a specific gravity from 0·96 to 0·966; it softens at 30° C., becoming plastic, so that it may be moulded by the hand, but it does not liquefy until 68° C., while at 0° C. it is hard and brittle.

On the composition of wax.—The term wax was originally applied only to the product secreted by bees; it is now, however, made to include a number of bodies of similar character, derived from both the vegetable and animal kingdoms, and the principal of which we have already referred to. They are compounds of the higher members of the fatty acids, partly in the free state, partly combined with alcohol radicals, but they do not contain glycerine like the fats. Wax is a mixture of three different substances: *myricin,* insoluble in boiling alcohol and consisting of palmitate of myricin; *cerotic acid,* formerly called cerin, soluble in boiling alcohol and crystallising on cooling; and *cerolein,* which remains dissolved in the cold alcoholic liquid.

They are but little soluble in alcohol and sometimes quite insoluble; soluble in ether, in oils fixed and volatile, chloroform, and sulphide of carbon; they burn with a bright flame when heated in the air, and are with difficulty saponified by boiling with potash, but more easily by fusion with the solid alkali.

Bleached wax contains, according to Lewy, 82·2 per cent. of carbon, 13·4 hydrogen, and 6·4 of oxygen. It is decomposed by dry distillation, giving off water, acetic acid, propionic acid, and then a substance called wax butter, it forming on cooling a white butter-like mass; afterwards a liquid, called wax oil, passes over, a carbonaceous residue finally remaining.

THE ADULTERATIONS OF HONEY AND WAX.

The more usual adulterations of honey are with various forms of *starch,* as those of the *potato* and *wheat,* and with *starch* and *cane sugars.*

Other adulterations mentioned by Mitchell and Normandy are with *chalk, hydrated sulphate of lime, and pipe clay.*

The starch is not only added for the sake of weight and bulk, but to improve the colour of very dark honey, and to correct a sharp and acidulous taste which old honey is apt to acquire.

The adulterations of wax.—Wax is stated to be sometimes adulterated with starch, as also with animal fats, as mutton suet.

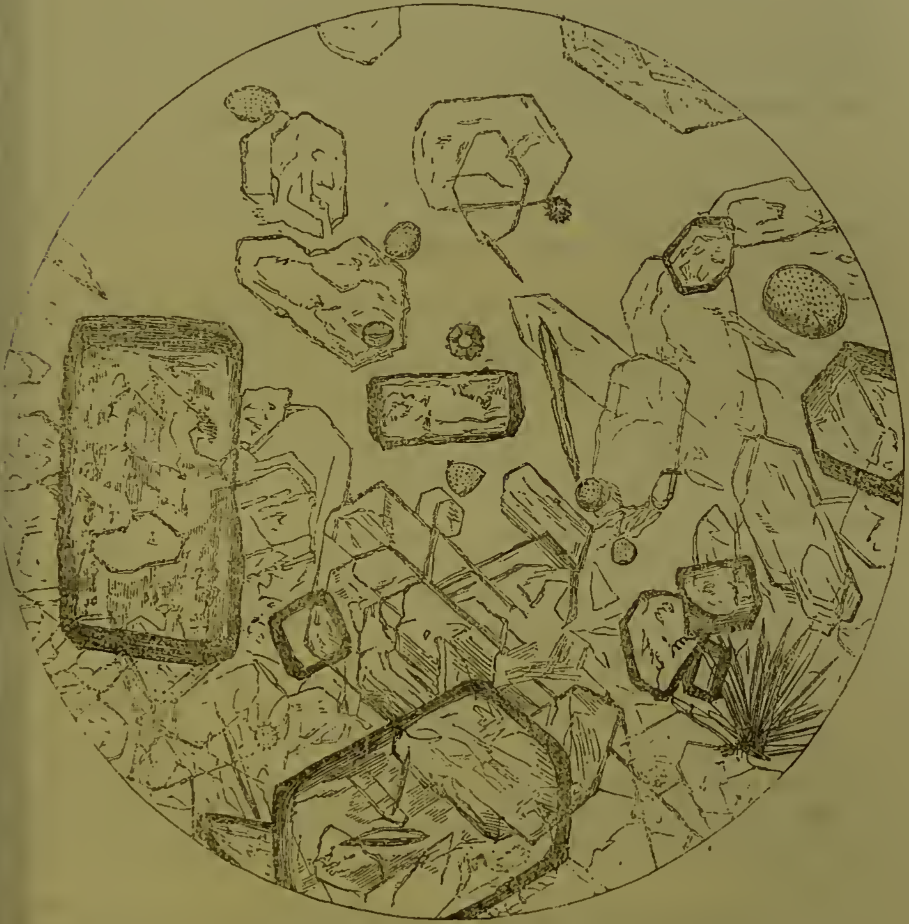
THE DETECTION OF THE ADULTERATIONS OF HONEY.

Of the adulterations practised upon honey, some are very easy of detection, and others difficult, if not impossible.

The general method of proceeding in the examination of honey, with a view to discover whether it is adulterated or not, is as follows:—

A little of the honey is to be examined under the microscope, when, if it contain unboiled starch, the granules will be visible, and may be identified by the characters which they present. If none are to be seen, a small quantity of tincture of iodine is to be added, which will show whether starch is present or not in any form.

Fig. 71.



Honey adulterated with CANE SUGAR. The thick irregular crystals are those of cane sugar. Magnified 200 diameters.

The starch, as well as any insoluble and inorganic material which may be present, may also be discovered by dissolving a portion of the honey in warm water, when a deposit will occur after a time. This deposit should be examined, in the first instance, by the microscope; and if it is not found to be of an organic nature, it most probably consists of *chalk*, or *gypsum*. If it effervesce, it is no doubt chalk; and if not, we must then proceed as described under 'Water,' for the analysis of the last-named substance. For the quantitative determination of inorganic matter in honey, nothing more is requisite in ordinary cases than to collect, dry, and weigh the residue deposited from the solution of a given quantity of honey in water, or to take the weight of the ash.

The adulterations of honey, the discovery of which is more difficult, are those with *cane* and *grape sugar*.

Cane sugar becomes charred on the addition of sulphuric acid, and it is stated that grape sugar does not; this distinction, however, does not apply to honey, for it also becomes charred, and for the very good reason that cane sugar is present in all honey, and in new honey in considerable amount, as also organic matter, including particularly pollen.

There are, however, four ways in which the presence of added *cane sugar* in honey may be determined, two of them being supplied by the microscope. The first is by the size, and especially by the thickness of the crystals of sugar; their shape is essentially the same as those of honey. The crystals of added cane sugar differ from the crystals proper to honey in being much larger, thicker, and in their less regular shapes; the angles being acted upon by the fluid part of the honey, and thus in part melted down.

The second is, supposing brown sugar to have been used, by the presence of the sugar acari, discernible either on the surface of a solution of honey in water, or in the residue deposited from it, or by that of fragments of the sugar-cane, the dotted cells of which are particularly characteristic.

The third method is chemical, and consists in the conversion of the cane into grape sugar, and its quantitative estimation in that form in the usual manner. If the quantity met with is very large indeed, we may infer that cane sugar has been added; but we must speak on this point with some reserve, since the only quantitative estimations hitherto made of the amounts of cane sugar actually present in honey are the four by ourselves, and inserted in the previous part of this article.

The fourth method for ascertaining the presence of cane sugar in honey and of estimating its amount, is, as already shown in the article on 'Sugar,' afforded by the polariscope.

The adulteration of honey which, so far as we are aware, it is scarcely possible in many cases to detect, is that by *starch sugar*, since this possesses the same chemical properties as the sugar of honey. As glucose is usually made by boiling with sulphuric acid, and as the excess of this is sometimes neutralised with chalk, the presence of notable quantities of sulphate of lime affords strong evidence of adulteration with sugar of starch. Pure honey gives only a very trifling amount of ash.

THE DETECTION OF THE ADULTERATIONS OF WAX.

The only two adulterations which have been described are with *starch* and *animal fats,* as mutton suet. The first will be detected by an examination with the microscope of the residue left after the exhaustion of the wax with ether, while the presence of most foreign fats will be readily discriminated by ascertaining the melting point, in the manner fully described in the article on 'Butter.'

CHAPTER XI.

FLOUR AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any other added farina than that indicated by the name under which it is sold ; alum or any other added mineral substance.

The term flour may be applied to the meal or powder obtained by the grinding of almost any species of grain or seed, but we shall treat in the present article chiefly of those descriptions of grain and flour which are most in use in this country as articles of diet, as *wheat*, *rye*, *oats*, *barley*, *maize*, and *rice*.

Each of these flours consists of *nitrogenous*, *non-nitrogenous* and *mineral* elements or constituents ; the nitrogenous embrace chiefly *glutin*, or *gliadin*, *fibrin*, *albumen*, *casein*, *cerealin*, together with certain modifications of some of the foregoing ; the non-nitrogenous are *sugar*, *dextrin*, but chiefly *starch*, *fat*, and *cellulose* ; the mineral are for the most part *alkaline phosphates* and *silicates*, especially *phosphate* and *silicate of potash*.

We shall treat of each of the flours above enumerated under separate headings, and first of

WHEAT FLOUR.

There are several distinct species of wheat : that which is chiefly cultivated in this country is the *Triticum vulgare* ; of this there are two varieties—*T. æstivum*, or summer wheat ; and *T. hybernum*, or winter wheat : the former is sown in the spring, and the latter in the autumn. Of these varieties, again, there are several modifications, into the description of which it is, however, not necessary to enter on the present occasion.

Wheat seeds or grains, as brought to the market, and as supplied to the miller, are deprived of their *paleæ*, or husks.

The number of parts into which ground wheat is separated, and the amount of each yielded by given quantities, vary according to the characters of the wheat, and the processes adopted by different millers.

In wheats which are hard the integuments separate with difficulty, and therefore the flour produced from these usually contains a greater proportion of adherent bran than do those flours procured from wheats which are soft, and which part with their epidermic coverings more readily.

According to Mr. Hard, a miller of Dartford, in Kent, the following are the products, with the quantities obtained, of one quarter, or eight bushels of ground wheat:—

'*Produce of One Quarter of Wheat, weighing* 504 *lbs.*

Flour	392 lbs.
Biscuit, or fine middlings	10 ,,
Toppings, or specks	8 ,,
Best pollard, Turkey pollard, or twenty-penny	15 ,,
Fine pollard	18 ,,
Bran and coarse pollard	50 ,,
Loss sustained by evaporation, and waste in grinding, dressing, &c.	11 ,,
	504 lbs.'

COMPOSITION OF WHEAT FLOUR.

We have already enumerated all the more important constituents which enter into the composition of the grain of wheat, and of the flour made therefrom. The grain of wheat differs from that of the other cereals principally in the peculiar physical characters possessed by its chief nitrogenous constituents, and especially *glutin*, or *gliadin*; crude gluten being a mixture of this with fibrin, and possessing, as will be seen hereafter, in the moist state, strongly adhesive properties. These are found to be practically of great value in bread-making, causing the dough to retain more strongly the carbonic acid evolved during fermentation, whereby the bread is rendered porous and light; and this is one of the chief reasons why the flour of wheat is preferred for bread-making to that of all other grains. We shall now describe in detail all the more important, and especially the nitrogenous, constituents of wheat flour. The particulars which will be given relative to these will apply in great part to the other cereals.

Crude gluten.—Crude gluten, as shown below, consists of several substances, and hence its properties partake to some extent of the characters of its constituents.[1] Although water exerts such an effect upon it in rendering it adhesive and tenacious, yet it is entirely insoluble in that menstruum. When freed from moisture it is tasteless, more or less transparent, and shiny. It is soluble in caustic

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[1] According to Von Bibra it has the following composition:—

	1	2	3	4
Fibrin	70·95	71·55	69·40	70·48
Glutin	14·40	16·00	17·57	16·92
Casein	8·80	6·53	7·30	6·33
Fat	5·85	5·92	5·73	6·27

potash and other alkalies, and is precipitated from its solution by most dilute acids. It is soluble in strong acetic acid. Digested in water containing from one to two thousands of hydrochloric acid, it gradually dissolves, furnishing a liquid which is lævorotatory, and in which the gluten comports itself with heat and reagents exactly as does albumen.

Glutin.—The above remarks apply to the crude gluten, but the pure *glutin, gliadin*, or vegetable gelatin, in its hydrated condition, forms a liquid of the consistence of varnish, and which is susceptible of being drawn out into silky-looking threads. When obtained from its alcoholic solution, treated with ether and dried *in vacuo*, it forms a hard, brittle, and opaque mass. When simply evaporated from its alcoholic solution, it resembles in its physical characters animal gelatin.

Glutin is soluble in dilute alcohol of from 40 to 80 per cent., but only with difficulty in absolute alcohol, from which it is deposited in the form of a white powder. It is only very slightly soluble in cold, but more freely in hot water, the solution yielding precipitates with gallotannic acid, basic acetate of lead, and several other metallic salts. With ferric sulphate, mixed with ammonia, it gives an orange-coloured or brownish precipitate, in which respect likewise it resembles animal gelatin. It dissolves, giving rise to a blue colour, in hydrochloric acid; in nitric acid it also dissolves, but is again precipitated on the addition of water. It is entirely soluble in tartaric and acetic acids, but only partially so in phosphoric acid. It is also soluble in the fixed alkalies, less so in ammonia, and the alkaline solutions afford precipitates with metallic and some other salts. With mercurous nitrate it gives rise, in the moist state, to a bright red colour; with strong sulphuric acid and sugar, to a yellow colour, which after half-an-hour changes to violet.

The following is the composition of pure glutin, according to Ritthausen:—

Carbon	52·49
Hydrogen	6·97
Nitrogen	18·02
Oxygen	21·41
Sulphur	0·85
Ash	0·26

It would appear that the albuminous substances entering into the composition of crude glutin have really nearly the same percentage composition as the other albuminoids. Gündsberg states that glutin, or gliadin, is not a simple proximate principle, for cold water extracts from it a brown substance containing nitrogen and sulphur, while the residue, treated with boiling water, yields a solution which on cooling furnishes a substance free from sulphur, which has nearly the same composition as animal gelatin, and which Gündsberg regards as the true glutin, or vegetable gelatin.

Fibrin.—This is the portion of crude glutin of wheat and other cereals which is insoluble in alcohol. In its moist state it forms a greyish-white elastic mass, but when dry a horny substance, which recovers its former characters by maceration in cold water. It is soluble in acetic, hydrochloric, and phosphoric acids; also in the alkalies, including ammonia, and is precipitated from these solutions on neutralisation. Acording to Scherer, fibrin contains 15·8 per cent. of nitrogen. Later analyses correspond in the main with the foregoing, but in three analyses made by Dumas and Cahours the nitrogen varied as follows:—15·8, 16·0, and 16·4.

It undergoes gradual alteration in contact with moisture, is transformed during germination, giving rise in the case of wheat and other cereals to the formation of diastase.

Casein,—frequently called *legumin,* is found abundantly in the seeds of the leguminosæ, and in small amount in wheat and other cereals. When dried from its alcoholic solution it is of a greyish-white colour, and readily reducible to the state of powder. It is soluble in boiling alcohol and in cold dilute acetic acid, but it becomes insoluble under certain circumstances, as when precipitated by ammonia from its solution in acetic acid, when boiled for a short time with water, or even when left in contact with it or with dilute alcohol.

Albumen.—The albumen deposited by heat from vegetable solutions is usually in the crude state, and is contaminated by colouring matter and other substances. For its purification the precipitate must be washed with water, and then with boiling alcohol and ether. Its solution coagulates at from 61° to 63° C., and at a little higher temperature is converted into a solid mass. If the solution is very dilute, the albumen is deposited in flocculi. Albumen thus coagulated is white, opaque, and elastic; when dried it is of a yellow colour, brittle, and translucent. After having been dried, it absorbs water when immersed in it, and assumes its original characters, and if dried at a temperature below the point of coagulation, it likewise re-acquires its solubility to any extent in water.

It is insoluble in alcohol and ether, and hence it is precipitated by strong alcohol added to its aqueous solution, the precipitate, if the alcohol is added in small quantity, being soluble in water. When alcohol is added to a somewhat dilute solution of albumen, the liquid after a while forms a gelatinous mass, which is liquefied by heat. Coagulated albumen may be made to dissolve in alcohol by the addition of an alkali. Nearly all acids precipitate albumen from its solution, especially nitric acid. Strong nitric acid with heat dissolves coagulated albumen, forming a blue or violet solution. Tribasic phosphoric acid, acetic, tartaric, and most other organic acids, do not form precipitates in moderately concentrated solutions, but when added to highly concentrated solutions the liquid solidifies to a jelly, which becomes liquid like gelatine when heated. In solutions of albumen to which common salt has been added, the albumen is precipitable by phosphoric, acetic, and other acids, or the albumen may be precipitated from the same acid solutions by means of salt, the precipitation being facilitated by the action of heat.

Albumen is soluble in weak solutions of alkalies, but a strong solution of potash, added in considerable quantity to a solution of albumen, forms a gelatinous mass. Alkaline carbonates prevent its coagulation by heat.

It has the same atomic composition as the other albuminoids, and contains, according to the best authorities, 15·8 per cent. of nitrogen.

Cerealin.—A nitrogenous substance approximating closely in its properties to diastase. It is contained in the membrane immediately surrounding the seed, called epispermium. It has the property of converting starch into dextrin, sugar, and lactic acid. This power is strikingly exemplified by adding an infusion of bran to a thick decoction of starch, which is quickly transformed as described above, the decoction becoming thin, limpid, and sweet, when kept at a temperature of from 40° to 50° C.

To obtain cerealin in a separate state, bran is treated with repeated quantities of dilute alcohol, it being pressed after each addition of the spirit. In this manner the whole of the sugar and dextrin are removed, the cerealin being left behind. The bran is next treated with water; this dissolves out the cerealin, and the aqueous solution being evaporated at 40° C., the cerealin is obtained in a pure state, it being soluble in water, but insoluble in alcohol and ether.

A solution containing cerealin coagulates at 75° C., and is precipitated on the addition of alcohol and by dilute acids. Alkalies prevent its action on starch. Once coagulated, it is no longer soluble in acids and alkalies, but it is still capable of slowly acting upon starch. Up to a temperature of 70° C. it retains its power of transforming starch, but not beyond that temperature, whereas diastase retains its power up to 90° C.

It would appear from the investigation of Mouriès that bran contains other substances besides cerealin which possess the power of converting starch, for he states that bran freed from cerealin, especially the perispermium, is more active than cerealin itself, and possesses the power of decomposing starch even at 100° C.

Starch.—The only other constituent of flour which it will be necessary to notice is the *starch*, which forms nearly two-thirds of its weight. It belongs to the class of carbohydrates, which includes sugar, into which during digestion it is converted, the sugar being conveyed by absorption into the circulation, and broken up during respiration into carbonic acid and water, heat being developed during the process.

The following analyses exhibit the precise percentage composition of different descriptions of wheat and wheat flour:—

Wheat (entire).—Peligot.

	White Flemish Wheat, 1841.	Hardy Wheat, 1843.	Trouselle Blanche, 1842.	Odessa Wheat.	Blé Hérisson.	Poulard Blé Conique, 1844.	Poulard Blé Conique, 1846.	Mitadin du Midi.	Polish Wheat, 1844.	Spanish Wheat.	Tanga Rock Wheat.
Water	14·6	13·6	14·6	15·2	13·2	14·4	13·2	13·6	13·2	15·2	14·8
Fatty matters	1·0	1·1	1·3	1·5	1·2	1·0	1·2	1·1	1·5	1·8	1·9
Nitrogenous matter insoluble in water	8·3	10·5	8·1	12·7	10·0	13·8	16·7	14·4	19·8	8·9	12·2
Soluble nitrogenous matter	2·4	2·0	1·8	1·6	1·7	1·8	1·4	1·6	1·7	1·8	1·4
Soluble non-nitrogenous matter, dextrin	9·2	10·5	8·1	6·3	6·8	7·2	5·9	6·4	6·8	7·3	7·9
Starch	62·7	60·8	66·1	61·3	67·1	59·9	59·7	59·8	55·1	63·6	57·9
Cellulose	1·8	1·5	—	—	—	1·5	—	1·4	—	—	2·3
Saline matter	—	—	—	1·4	—	1·9	1·9	1·7	1·9	1·4	1·6

Wheat.

	Polson, American.	Polson, Scotch.	Pillitz.				
Water	10·8	14·8	12·7	12·4	12·3	12·3	12·3
Fat	1·2	1·2	1·6	1·7	1·6	2·3	1·8
Nitrogenous substances	10·9	7·0	9·9	9·8	12·1	11·2	11·0
Gum and dextrin	3·8	5·3	1·5	2·0	4·6	4·0	1·6
Sugar	—	—	1·4	1·4	0·9	0·5	0·5
Starch	62·3	56·9	64·6	64·4	61·3	62·2	63·1
Cellulose	8·3	12·4	2·7	2·6	4·2	4·3	3·8
Mineral matter	1·6	1·5	1·7	1·5	1·9	1·5	1·6
	98·9	99·1	96·1	95·8	98·9	98·3	95·7

Wheat Flour.
(Vauquelin.)

	French.	Odessa (Hard).	Odessa (Soft).	Paris Flour.	Inferior Flour.
Starch . . .	71·49	56·5	62·00	72·8	67·78
Gluten . .	10·96	14·55	12·00	10·2	9·02
Sugar . . .	4·72	8·48	7·56	4·2	4·80
Gum . . .	3·82	4·90	5·80	2·8	4·60
Bran . . .	—	2·30	1·20	—	—
Water . . .	10·00	12·00	10·00	10·0	12·00

Dumas.

Wheat Flour.		Odessa Flour (Flinty).		Odessa Flour (Soft).	
Water . .	10·00	Water . .	12·00	Water . .	10·00
Gluten . .	10·96	Gluten . .	14·55	Gluten . .	12·00
Starch . .	71·49	Starch . .	56·50	Starch . .	62·00
Sugar . .	4·72	Sugar . .	8·48	Sugar . .	7·36
Dextrin . .	3·32	Dextrin . .	4·90	Dextrin . .	5·81
		Bran . . .	2·30	Bran . .	1·29
	100·49		98·73		98·46

According to Millon, the nitrogen in wheat varied in 22 different samples from 1·588 to 2·729, equal in nitrogenous substance from 10·05 to 17·27 per cent., while Poggiale found an average of 14·4 per cent. of gluten in dried wheat.

Wheat Bran.

	Fürstenburg.	Poggiale.
Gluten	10·84	13·0
Albumen	1·60	
Starch	22·66	21·7
Sugar	—	1·9
Gum	5·28	7·9
Fat	2·82	2·9
Water	10·30	12·7
Ligneous matter	43·98	34·6
Chloride of potassium	0·23	5·5
Sulphate of potash	0·24	
Phosphate of magnesia	0·93	
Carbonate of lime	0·37	
Silica	0·75	
	100·00	100·2

Some idea may be formed from an examination of the above analyses of the great value of wheat flour as an article of diet. Like milk, it contains all the elements necessary to the growth and sustenance of the animal body, nitrogenous, non-nitrogenous, and mineral. It is, in fact, the type of a perfect food, and well deserves the appellation which has been bestowed upon it of the 'staff of life.'

The analyses of bran given above are particularly interesting and important, for they show that bran contains really some of the most valuable constituents of the grain. It contains a large amount of nitrogenous matter, including the very important principle cerealin, the properties of which we have already described, as also much oily matter. By sifting out the bran, therefore, we render the meal much less nutritious; this will be more apparent when we state that the bran rarely forms less than one-fourth, and is often considerably more, of the whole weight of the grain. It is of importance that this fact should be generally known, as the knowledge of it may serve in some degree to correct the preference given to very white bread, and the notion that whiteness and quality go together. The very reverse of this is often the case.

It should be known also that the small or tail corn, which is usually separated from the other corn, and used by the farmer himself, is richer in gluten than the large-sized grain.

Ash of wheat.—Very many analyses of the ash of wheat have been made, of which we append the principal. The mineral constituents contained in wheat were at one time invested with a peculiar interest, from the supposition that a knowledge of them would prove of great value by enabling the agriculturist to treat the soils on which the grain is grown in the manner best adapted to the nature of the crop. Thus his object would be to put into the soil those constituents which were found to be of most importance in the constitution of the ash. This supposition is, however, not correct to the extent formerly believed, as will presently appear.

Messrs. Way and Ogston deduce from their numerous analyses of the ash of cereals the following general conclusions:—

Ashes of Wheat.

	Ogston and Way.				
	Hopeton, 9 samples.	Spalding.	Creeping, 3 samples.	Red straw, white. 7 samples.	Old red lammas.
Potash . . .	27·1–36·4	29·8	28·9–31·2	26·7–31·1	34·2
Soda . . .	0·1– 6·1	5·3	1·3– 2·1	0·6– 3·8	4·5
Lime . . .	1·3– 8·2	2·9	1·5– 6·8	1·15– 6·9	3·2
Magnesia . .	9·9–14·0	11·1	12·4–13·1	9·5–14·2	9·6
Oxide of iron . .	0·1– 2·0	0·2	0·1– 1·4	0·1– 3·3	2·1
Sulphuric acid .	trace– 1·9	0·1	0·6– 1·6	0·1– 0·6	0·3
Silica . . .	1·4– 5·6	2·2	1·3– 5·3	2·1– 9·7	5·5
Carbonic acid . .	0·2	0·2	—	—	—
Chloride of sodium .	0·3– 1·6	—	—	0·34	—
Phosphoric acid .	40·0–49·2	48·2	45·6–48·5	46·6–49·6	40·6
Ash in 100 parts of dry substance .	1·7–2·05	2·05	1·85–1·95	1·8– 2·1	2·1

Ashes of Wheat.

	Ogston and Way.				T. Herapath.		Lawes and Gilbert.
	French	Egyptian.	Odessa.	Maria-nople.	3 samples grown on irrigated land.	2 samples on non-irrigated land.	Mean of 23 samples.
Potash . . .	32·4	36·6	30·3	35·8	20·0–31·9	33·1–35·4	29·35
Soda . . .	2·3	0·5	1·0	9·1	8·9–15·0	2·9– 3·1	1·1
Lime . . .	3·5	4·3	3·2	2·05	0·9– 1·4	2·2– 5·6	3·4
Magnesia . .	13·9	11·1	14·3	14·1	10·6–12·9	9·1–10·1	10·7
Oxide of iron . .	1·0	1·2	0·9	trace	—	—	2·4
Sulphuric acid .	0·35	0·2	—	0·2	0·1– 0·2	trace	—
Silica . . .	3·05	5·0	4·5	5·0	0·1– 0·2	trace	2·5
Carbonic acid . .	—	—	—	—	—	—	—
Chloride of sodium .	—	—	—	—	—	trace	0·13
Phosphoric acid .	43·5	41·0	45·8	34·4	46·1–48·7	48·2–50·0	49·7
Ash in 100 parts of dry substance .	1·7	2·2	1·7	1·9	2·3	2·5	2·0

That the amount of ash is not affected in any definite way by the nature of the soil. It is greatest on clay soils, less on calcareous, and least on sandy soils. The strongest straw contains most ash. The ash in the grain varies as much in samples grown on the same soil as in those from different soils, and bears no definite relation to climate or to variety. And, further, that the total amount of ash abstracted from the soil by the grain is the same, whatever be the weight of the crop.

That not only the amount but the composition of the ash appears to be independent of the nature of the soil; the predominance of any constituents, as lime or silica, by no means causes an excess of that same constituent in the plant, nor does it appear that different bases have any tendency to replace each other; an abundance of soda does not cause that alkali to take the place of potash.

Respecting these conclusions, different results have been arrived at by other chemists, as Daubeny, Malagutti, and Durocher.

The differences in the amount of ash in the grain, straw, and chaff relate chiefly to silica; if this be deducted, the rest of the constituents, it is affirmed, exhibit no perceptible variation; the ash of barley and oats differs from that of wheat only in the larger amount of silica contained in the two former; if this be deducted, no essential differences remain.

The following are certain average results obtained from observations upon 50 different samples of wheat, the particulars of which are given in 'Watts's Dictionary':—

The moisture in 100 parts of grain	varies from	9·5	to	13·5	mean	11·76
,, ,, ,, straw	,,	10·4	,,	14·0	,,	11·76
,, ,, ,, chaff	,,	11·0	,,	14·0	,,	12·24
Specific gravity of the grain	,,	1·313	,,	1·413	,,	1·374
Weight in lbs. of 1 bushel of grain	,,	58	,,	63	,,	61·8
,, of straw to 1,000 parts of grain	,,	730	,,	1327	,,	1047
,, of chaff ,, ,, ,,	,,	116	,,	278	,,	181
Amount of ash in 100 parts of dry grain	,,	1·68	,,	2·19	,,	1·99
,, ,, ,, ,, straw	,,	3·61	,,	12·29	,,	5·31
,, ,, ,, ,, chaff	,,	7·93	,,	18·76	,,	13·95

THE ANALYSIS OF FLOUR.

As it is frequently a matter of much importance to determine the composition of samples of wheat flour, we will now describe the various steps by which the analysis may be effected.

Determination of the gluten.—A weighed quantity of flour is to be made into a paste, and well kneaded, either on a sieve or in a piece of muslin, water being poured over it until it ceases to acquire a milky colour; the water carries away the starch, and dissolves out the albumen, sugar, gum, and salts, while the mass left on the filter consists of 'crude gluten.'

Glutin.—This substance is obtained by digesting crude gluten for several hours with alcohol of 80–85 per cent. The alcohol is then boiled and the supernatant liquid decanted. The mass of gluten is again boiled several times with alcohol of 75 per cent. The united alcoholic liquids which contain the glutin, casein, and a little oil become turbid on cooling, principally from the deposition of the casein. Half the alcohol is now to be distilled off, when flocculi of casein mixed with glutin and fat become deposited. The remainder contains the glutin, which is obtained by evaporation and drying over the water-bath, whereby the casein which still remains is rendered insoluble, when finally the glutin is redissolved in alcohol or dilute acetic acid, from which it may be obtained in a state of purity by evaporation. To purify the *casein*, it must be dissolved in alcohol of 50 per cent., and the hot solution filtered through calico, then left to cool, it being frequently agitated while the deposit is forming.

Fibrin.—This is insoluble in alcohol and forms the chief part of the crude gluten; it is left in nearly a pure state after the action of the alcohol, but it still contains small quantities of starch, husk, cellulose, and oil, from which it may be separated as follows:—It must be dissolved in a dilute solution of potash, precipitated by acetic acid, and after drying the fat is to be removed by means of ether. Or the fibrin after exhaustion with alcohol may be dissolved in very dilute hydrochloric acid, from which it may be obtained as a precipitate on neutralisation with ammonia. The hydrochloric acid solution behaves just like that of the fibrin of muscle, showing the identity of vegetable and animal fibrin.

For the other constituents of the wheaten flour we must search in the water which has passed through the sieve.

Albumen.—This substance is procured, after the subsidence of the starch, by concentrating and then boiling the water, slightly acidulating with acetic acid. The albumen is coagulated, and may be separated after washing with hot alcohol and ether, by filtration through a weighed filter.

Casein or mucin.—We have already shown how this substance may be obtained from the crude gluten in a state of purity, but for its quantitative estimation we must proceed as follows:—After the separation of the albumen, acetic acid is to be added to the filtrate. This throws down the casein, which may also be collected on a weighed filter.

Estimation of total nitrogen.—The total amount of nitrogen is ascertained by the combustion of from 1 to 2 grammes of the flour with soda-lime. The quantity of nitrogen obtained, multiplied by 6·33, represents the amount of nitrogenous substances.

Starch.—The starch, suspended in the water, gradually subsides, when it may readily be collected on a filter, washed, dried, and weighed. Or a weighed quantity of the flour may be exhausted with water, which will remove the sugar and dextrin. The insoluble residue is converted into glucose in the usual manner by the action of dilute sulphuric acid, as will be found described in the article on 'Sugar,' and the glucose estimated by means of the copper solution, the quantity of starch being calculated from the amount of the glucose found, 100 parts of glucose corresponding to 90 parts of starch.

Sugar and dextrin.—In a part of the watery solution referred to in the previous paragraph, the sugar is first estimated by the copper solution. The dextrin in the other portion is converted into glucose, and likewise estimated. 100 parts of glucose are equal to 95 parts of dextrin.

Oil.—A weighed quantity of the dried and bruised wheat or flour is treated two or three times with ether, until all traces of fat are removed. The ether is evaporated and the fat weighed.

Water.—The quantity of water is estimated by drying in the water-bath in the usual manner.

Mineral matters.—These are obtained by incineration, and their nature and amounts may be ascertained, should it be necessary to make a full analysis, by the adoption of the several processes which have been given elsewhere in this work, and most of which will be found described in the articles on 'Water' and 'Tea.'

To determine the quality of the crude gluten, a little instrument has been invented by Mr. Boland, termed an '*aleurometer.*'

Of this instrument the following description is given by Mr. Mitchell:—

'It consists of a hollow copper cylinder, about six inches long, and from three-quarters of an inch to an inch in diameter. It has two principal parts; the one, about two inches long, is closed at one end, forming a kind of cup capable of containing about 210 grains of fresh gluten; it screws into the remainder of the cylinder. The cylinder being charged with gluten, is heated to about 420° F. in an oil-bath. The gluten by this treatment swells, and according to its rise in the tube (which may be measured by a graduated stem) so is its quality. Good flours furnish a gluten which augments to four or five times its original bulk; but bad flours give a gluten which does not swell, becomes viscous and nearly fluid, adhering to the sides of the tube, and giving off occasionally a disagreeable odour, whilst that of good flour merely suggests the smell of hot bread.'

The proceeding adopted by the corn-chandler and the baker for the determination of the quality of wheaten flour is still more simple:

A small quantity (a few grains is sufficient) is made into a paste with water, and its quality judged of by the tenacity of the dough, as shown by the length to which it may be drawn into a thread, or the extent to which it may be spread out in a thin sheet.

STRUCTURE OF THE GRAIN OF WHEAT.

Several structures enter into the formation of the seed or grain of wheat, as well as that of the other cereals.

First, the seed is surrounded by membranes, called the testa; second, the surface of the seed proper is formed of angular cells, filled with glutinous and oily matter in a granular state; while the substance of the seed is made up of cells filled with starch corpuscles. Now each of the parts enumerated differ in the several cereal grains.

The testa is in part, but not entirely, removed in the process of grinding and dressing the flour, and the same is the case with the cells forming the surface of the grain.

The following is the exact structure of the grain of wheat:—

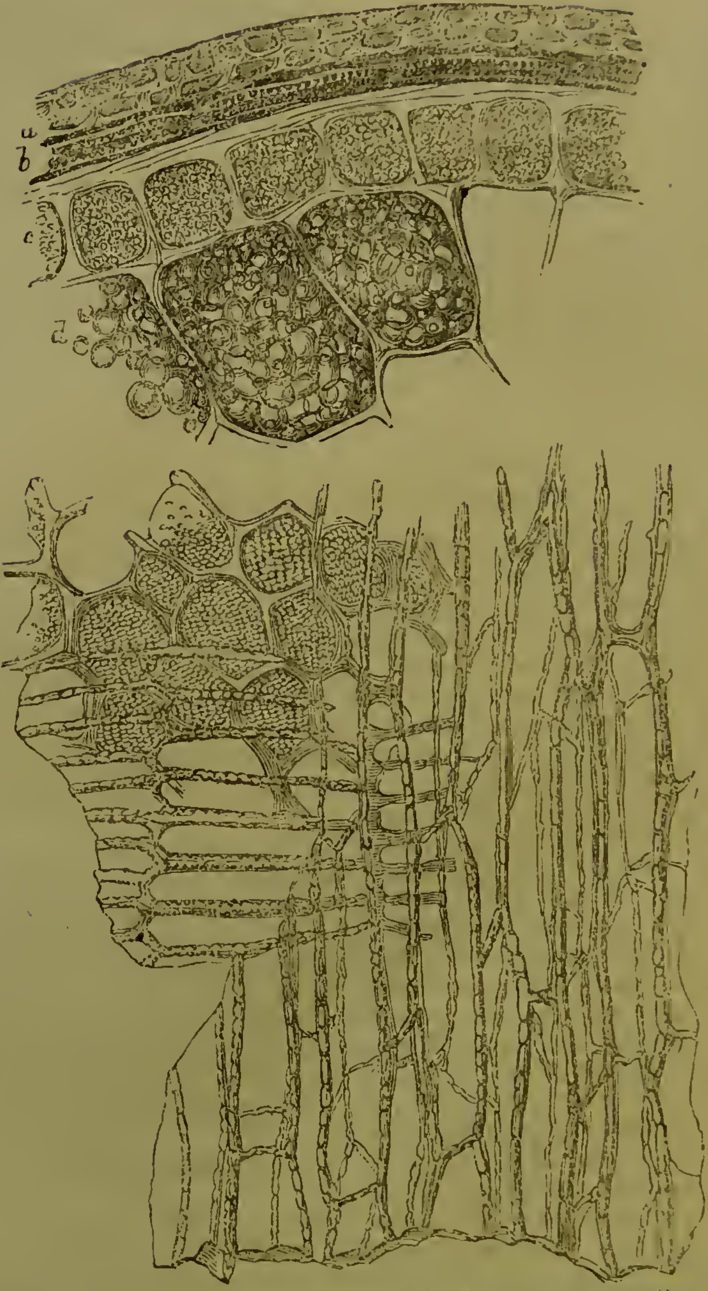
The testa, covering the immediate surface of the seed, consists of three layers of cells, two of which are disposed longitudinally to the axis of the seeds, and the other transversely. The longitudinal cells are large, and the margins distinctly beaded, especially the outer layer; the transverse cells are also beaded, but to a less extent.

The cells forming the surface of the seeds are large and angular; those of its substance are still larger, and each encloses a considerable number of starch corpuscles, which are smaller near the outer parts of the grain than towards the centre. These several layers of cells may be described as three distinct membranes.

The structure of the testa and of the substance of the seed is exhibited in the engravings (fig. 72).

Viewed with an object-glass magnifying 420 diameters linear, wheat starch is observed to consist of definite grains or particles; many of these are very small, others are of considerable dimensions, while there are but few of intermediate sizes: the small grains are

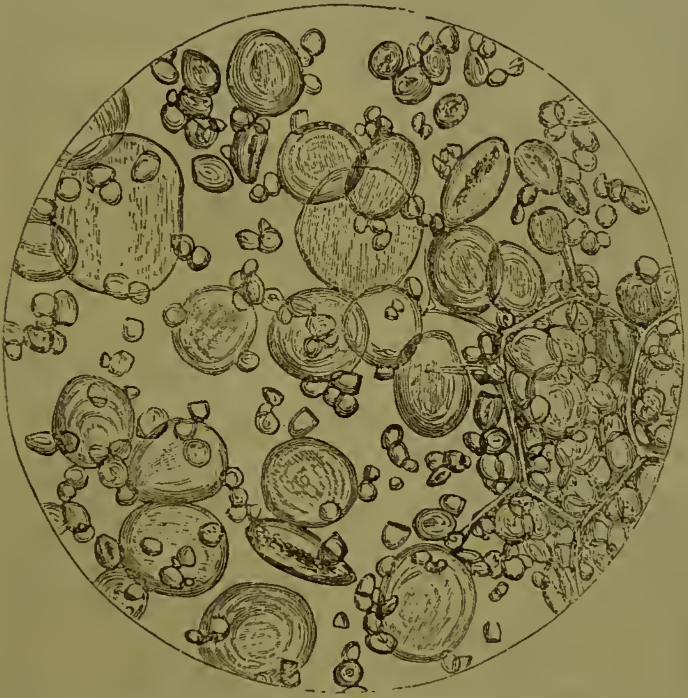
Fig. 72.



Testa and substance of seed of WHEAT. *Transverse* and *vertical* sections; *a a*, outer membrane; *b b*, middle; *c c*, inner membrane or surface of the seed proper. Magnified 200 diameters.

chiefly round, rarely oval, or muller-shaped, and for the most part provided with a central spot or hilum; the larger granules form rounded or flattened discs, with thin edges. Neither hilum nor concentric rings are *in general* perceptible on the larger discs, although in some few a central tubercle may be seen, as well as indistinct annuli. Occasionally some of the larger granules are more or less twisted or turned up at the edges, and when seen sideways, present the appearance of a longitudinal furrow, which has been erroneously described as a hilum: this appearance is, however, deceptive; it is really occasioned by the partial folding or curling of the grain on itself, whereby a central depression is produced, the corpuscle at the same time being viewed obliquely. We have frequently seen grains which when stationary presented a round and disc-like appearance, but which, in rolling over and presenting the edges to view, exhibited the longitudinal furrow described, an observation which clearly proves its nature. A few granules attain a very considerable size; these are less regularly circular, and being much flattened, exhibit but little shadow; sometimes their edges are faintly marked with radiating

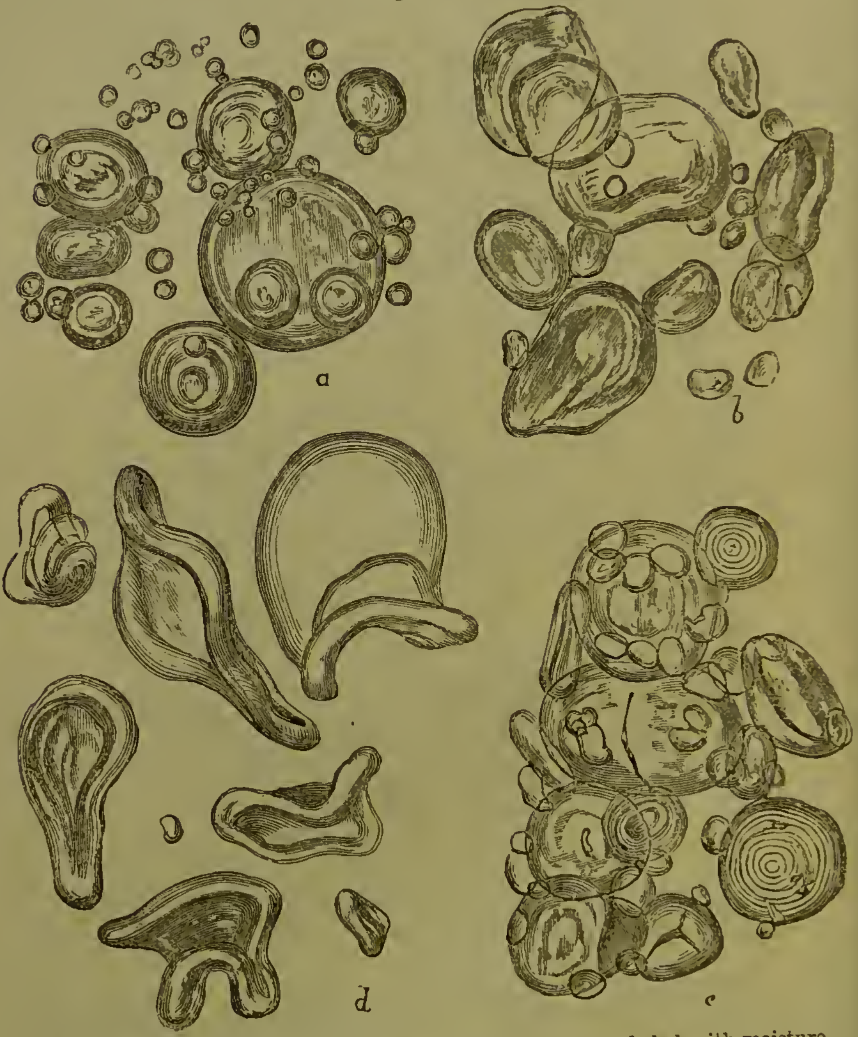
Fig 73.



This engraving represents the structure and appearances of the starch granules of WHEAT FLOUR, as also the characters of the *cellulose*. Drawn with the Camera Lucida, and magnified 420 diameters.

lines. Examined with the polariscope they exhibit a well-marked cross. Many of the above-described particulars, as also the characters of the cellulose, are well exhibited in fig. 73.

Fig. 74.

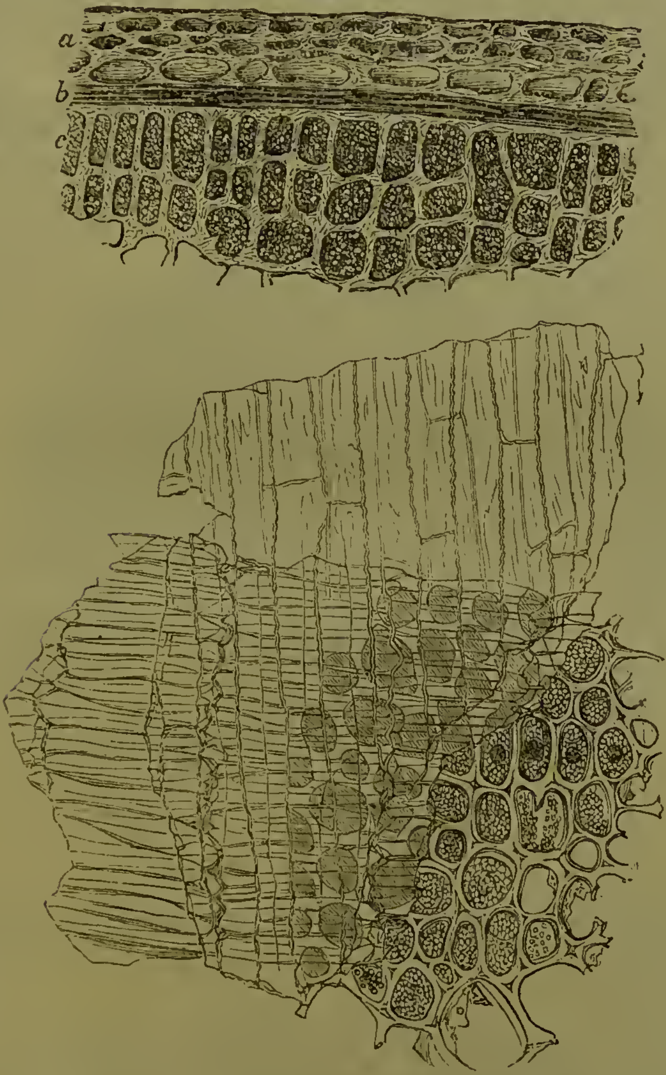


a, starch granules of *raw* wheat flour; *b*, ditto of the same *baked*, with moisture as in bread; *c*, *dry baked*; *d*, *boiled*, as in pudding. Magnified 400 diameters.

Not only, as has been already stated more than once, can the different starches be discriminated from each other by means of the microscope, but in many instances the agencies to which they have been exposed may be determined, as will be clearly perceived on an attentive examination of the engraving (fig. 74).

The differences between the raw, moist baked, and boiled starch granules of wheat and the other cereals are very marked: those of the dry baked are less marked; they are, however, on the average much larger than the raw granules, the form less regular, that of the smaller grains especially being a good deal altered; the shadows are less marked, and in some of the granules the concentric rings are rendered more conspicuous. To these illustrations of the variations in

Fig. 75.

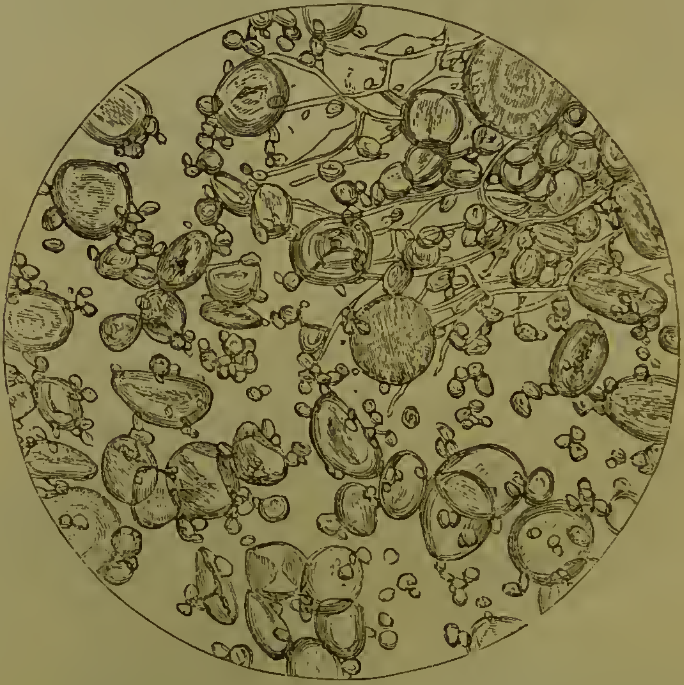


Testa and surface of seed of Barley. Magnified 200 diameters.

the condition of the granules of wheat flour a fifth might have been added representing the characters of the starch in *British gum* or *dextrin* made from wheat starch; in this the granules are destroyed to a great extent, but here and there granules and portions of granules may be discovered, often exhibiting the concentric rings and sufficient to serve for its identification, and to determine whether the gum was made from wheat or potato flour.

It is by means of British gum that the backs of postage labels are rendered adhesive, as may be shown readily by submitting a small portion scraped from the label to examination with the microscope.

Fig. 76.



This engraving represents the structure and characters of BARLEY STARCH, together with the *cellulose*. Drawn with the Camera Lucida, and magnified 140 diameters.

BARLEY FLOUR.

There are several distinct species of barley; that, however, which is commonly cultivated in this country is the *Hordeum distichon*, or two-eared barley.

As met with in commerce the seeds or grains are usually enclosed in the *paleæ* or husks; denuded of these, they form '*Scotch* or *pot barley*,' when rounded they constitute '*pearl barley*,' and this again reduced to powder is called '*patent barley*.'

Chemical composition.—The proportion of azotised compounds in barley is less than in wheat flour; it is deficient particularly in crude gluten, so that barley paste may be nearly all washed away in water.

The milky fluid obtained by washing barley paste, deposits, as well as the starch, a protein matter supposed to be *insoluble casein*: if this be digested with a solution of ammonia, it is dissolved, but is again thrown down on the addition of acetic acid; the liquid which has deposited the starch and insoluble casein still holds in solution a small quantity of albumen and some *soluble* casein.

The substance to which Proust gave the name of *Hordein* is stated not to be a definite compound, but to consist of starch and cellulose, with an albuminoid.

Barley flour is less nutritive than wheat flour and somewhat laxative; its starch corpuscles are less soluble, and therefore resist more the action of the gastric juice; the husk is slightly acrid.

The following analyses of barley and its ash have been made :—

Analyses of Barley.

	Von Bibra. In the meal.	Von Bibra. In the bran.	Polson. Air-dried grain. New Scotch.
Starch	59·950	42·008	52·7
Fat	2·170	2·960	2·6
Cellulose	—	19·400	11·5
Gum	6 744	6·885	4·2
Sugar	3·200	1·904	
Nitrogenous matter	12·981	14·843	13·2
Ash	—	—	2·8
Water	15·000	12·000	12·0

Ashes of Barley.

	Way and Ogston.		
	Chevalier. 5 samples.	Moldavian. 3 samples.	Long-eared. Nottingham.
Potash	20·8–37·2	19·8–31·6	32·0
Soda	0·5– 1·4	0·9– 4·9	1·2
Lime	1·5– 3·6	1·2– 4·2	3·4
Magnesia	2·9– 8·7	8·2–10·2	11·0
Oxide of iron	0·1– 2·1	0·1– 1·0	0·15
Sulphuric acid	trace– 2·7	0 3– 0·5	trace
Silica	17·3–32·7	24·6–30·4	21·12
Carbonic acid	—	—	0·5
Phosphoric acid	25·3–38·8	28·7–38·0	29·9
Chloride of sodium	2·3–11·1	trace– 1·5	0·7
Ash in dry substance	2·3– 2·7	2·1– 2·6	2·20

The Analysis of Barley.

This must be conducted very much in the same manner as that of wheat flour.

Structure of the Grain of Barley.

The testa of the grain of barley differs considerably from that of wheat. It consists usually of four layers of cells; they are smaller than those of wheat; the longitudinal cells, of which there are three layers, are not beaded, but those forming the outer layer have their margins slightly waved; those of the inner layer and of the transverse cells not being waved.

The cells of the surface of the grain are not nearly so large as those of wheat, and they form three layers, in place of one as in wheat. Those of its substance also differ from the corresponding cells of wheat, being more delicate, and presenting, when emptied of starch, a fibrous appearance (fig. 75).

The starch granules of barley resemble very closely in form and structure those of wheat, so that the description already given applies to some extent to the starch of barley.

Barley starch consists of small and large grains, with but few of intermediate size: the former, it is to be particularly observed, are three or four times smaller than the corresponding grains of wheat starch; and of the larger grains many are distinctly ringed, while a much greater proportion of them presents the longitudinal furrow, the nature of which has already been described. These characters are sufficiently well marked to allow of the discrimination by the microscopist of wheat and barley flour or starch. Examined with the polariscope, they exhibit a cross not nearly so strongly marked as in rye.

Considerable difference is observed between wheat and barley flour in the action upon them of boiling water and some other reagents; thus, after prolonged boiling, in the case of barley flour, a substance remains undissolved which has been denominated '*hordein*,' whereas wheat flour treated in the same manner is nearly all dissolved.

By the above characters, particularly by the minuteness of the small grains, and by the structure of the testa, barley starch or meal may be readily and satisfactorily discriminated when mixed with wheat flour (figs. 75 and 76).

RYE FLOUR.

The grass from which rye is obtained is the *Secale cereale*.

The seeds or grains resemble those of wheat, but are smaller.

Rye flour is rich in nitrogenised products, and it contains more sugar than wheaten flour; its paste, when repeatedly washed in water, breaks up, and becomes diffused throughout the liquid, the bran only being left behind; the milky liquid, after having deposited the starch, and after the separation of the albumen, is to be evaporated, when the residue will consist of sugar, oil, and the so-called '*soluble gluten*,' which may be dissolved out by means of alcohol.

Analyses of Rye.

	Fehling & Faisst. 7 samples. Dried at 100° C.	Poggiale. Mean of samples. Dried at 120° C.	Pillitz. Air-dried.
Starch . .	78·58–85·25	65·5	56·4
Fat . .		2·0	2·2
Cellulose . . .	1·24– 2·30	6·4	3·9
Gum and sugar .	—	—	6·8
Nitrogenous matter.	10·40–15·83	8·8	12·4
Ash . . .	1·90– 2·30	1·8	1·5
Water . . .	12·62–14·70	15·5	13·8

	Horsford and Krocker.—Dried at 212° F.			
	Rye flour from Vienna.		Rye flour from Hohenheim.	
Gluten and albumen . .	11·92	18·69	17·73	15·76
Starch	60·91	54·48	45·09	47·42
Woody fibre, gum, sugar .	24·74	24·49	35·77	35·25
Ash	1·33	1·07	2·43	2·37
	98·90	98·73	101·02	100·80
Moisture in fresh substance .	13·78	14·68	13·94	13·82

Rye Flour.

	Einhof.	Greif.	Boussingault.
Gluten	9·48	12·8	10·5
Albumen . .	3·28	3·0	
Starch . . .	61·07	58·8	64·0
Sugar . . .	3·28	10·4	3·0
Gum . . .	11·09	7·2	11·0
Cellulose . .	6·38	—	6·0
Fat, acid, loss . .	5·62	7·8	3·5
	100·20	100·0	98·0

Mineral Matter of Rye.

	Fresenius and Will.	Fresenius and Will.	Way and Ogston.
Potash	31·89	11·43	33·83
Soda	4·33	18·89	0·39
Lime	2·84	7·05	2·61
Magnesia	9·86	10·57	12·81
Oxide of iron	0·80	1·90	1·04
Phosphoric acid	46·03	57·81	39·92
Chloride of sodium	trace	—	—
Silica	1·42	0·69	9·22
Sulphuric acid	0·17	0·51	0·18
Coal, sand	2·66	—	—
	100·00	—	100·00

	Way and Ogston.—Unknown varieties.		
Potash	33·8	16·6	9·4
Soda	0·4	19·9	16·1
Lime	2·6	11·25	15·3
Magnesia	12·8	13·0	10·1
Oxide of iron	1·0	—	2·2
Sulphuric acid	0·2	0·5	2·6
Silica	9·2	3·6	14·6
Carbonic acid	—	—	—
Phosphoric acid	39·9	33·5	25·1
Chloride of sodium	—	1·6	4·2
Ash in dried grain	1·6	2·65	1·9

Rye flour is said to be somewhat laxative.

The roasted grains were frequently employed in the adulteration of coffee.

Structure of the Grain of Rye.

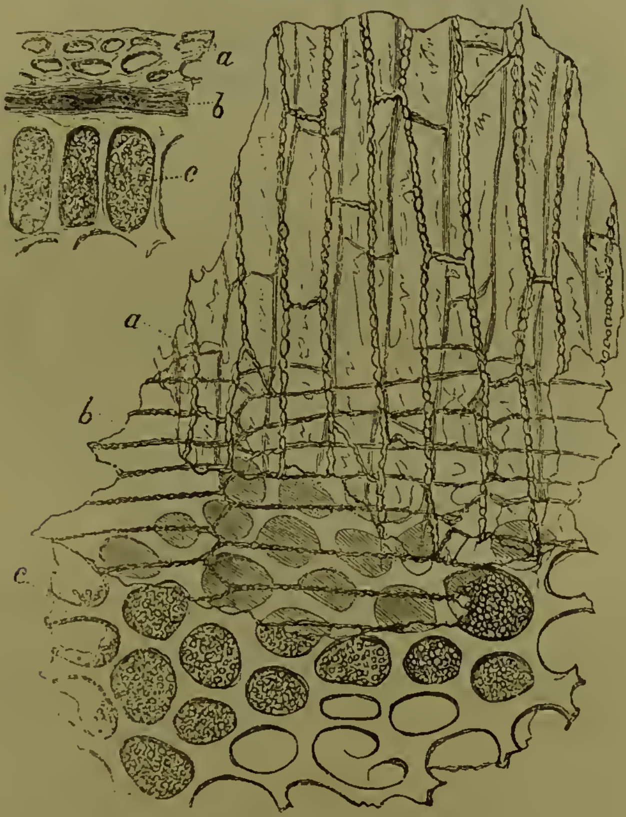
The testa of rye approaches somewhat closely in structure to that of wheat, as is evident on an examination of the subjoined engraving. There are, however, certain differences; thus, the cells of the first and second coats are smaller and much more delicately beaded; those of the third coat are also smaller and of a somewhat different form (fig. 77).

The starch granules of rye flour bear a general resemblance in form and size to those of wheat: there are these remarkable and satisfactory differences, however—viz., that the lesser grains are decidedly smaller than the corresponding grains of wheat, and that many of the larger granules of rye starch are furnished with a three or four-rayed hilum. Examined with the polariscope they exhibit a very strongly marked cross (fig. 78).

OAT FLOUR.

There are several distinct species of oats; that, however, which is chiefly cultivated in this country is *Avena sativa.*

Fig. 77.



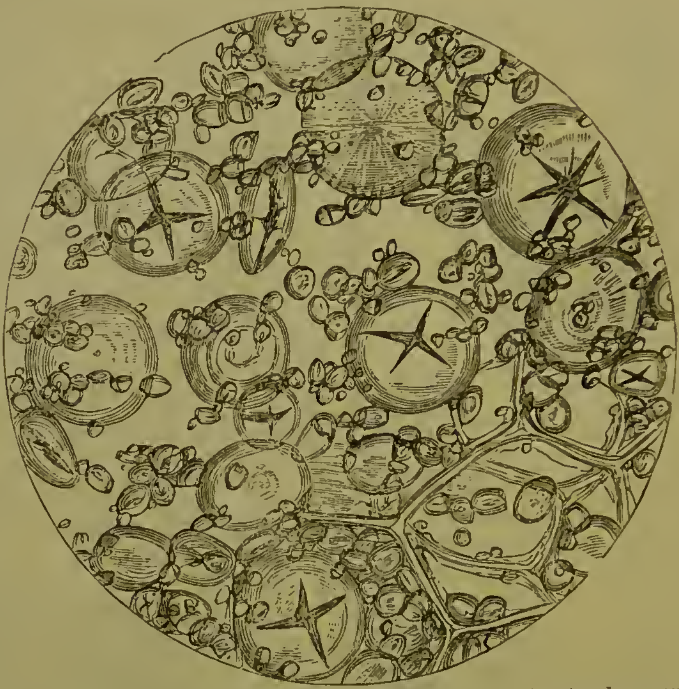
Structure of testa of RYE. Vertical and transverse views: *a a*, outer; *b b*, middle, and *c c*, inner coats. Magnified 220 diameters.

The oat grains or seeds are usually enclosed in their husks; when deprived of these they form what are known as *'groats,'* and these crushed constitute *'Embden groats.'*

Oat flour or meal does not form a dough or paste like wheat flour; notwithstanding which, however, it contains a large amount of nitrogenised matter; this exists principally in the form of *'Avenin,'* a substance analogous to soluble casein or legumin, and obtained in the same manner, by the addition of acetic acid.

'Oatmeal,' Pereira remarks, 'is an important and valuable article of food. With the exception of maize or Indian corn it is richer in oily or fatty matter than any other of the cultivated cereal grains; and its proportion of protein compounds exceeds that of the finest English wheaten flour; so that both with respect to its heat and fat making, and its flesh and blood making principles, it holds a high rank.'

Fig. 78.



This engraving represents the structure and characters of the starch granules of Rye Flour. Drawn with the Camera Lucida, and magnified 420 diameters.

Analyses of Oats.

	Fehling and Faisst. 6 samples dried at 100° C.	Fehling and Faisst. 2 samples, free from husk, dried at 100° C.	Poggiale. Shelled grain, dried at 120° C.	Pillitz. Air-dried grain.
Starch	70·24–76·41	82·30–82·90	61·9	54·1
Fat			6·1	2·7
Cellulose	10·00–11·39	0·92–1·41	3·5	7·8
Gum and sugar	—	—	—	4·1
Nitrogenous matter	10·69–15·59	14·12–14·16	11·2	14·1
Ash	2·65–3·01	2·06–2·13	3·61	2·4
Water	12·47–14·13	14·86–15·06	14·2	13·9

Scotch Oat, exclusive of husk.

	Norton and Fromberg.			
	Northumberland.	Ayrshire.	Ayrshire.	Northumberland.
Starch . . .	65·24	64·80	64·79	65·60
Sugar . . .	4·51	2·58	2·09	0·80
Gum . . .	2·10	2·41	2·12	2·28
Oil	5·44	6·97	6·41	7·38
Nitrogenous matter	18·69	19·01	20·81	19·91
Epidermis . .	1·18	2·39	2·84	2·28
Mineral matter .	2·84	1·84	0·94	1·75
	100·00	100·00	100·00	100·00

Ash of Oats.

	J. Norton.		Way and Ogston.			
	Potato.	Hopeton, 3 samples.	Hopeton, 4 samples.	Potato, 4 samples.	Polish.	Polish.
Potash . .	31·6	20·6–21·0	13·6–17·8	13·1–19·7	24·3	16·3
Soda . . .	—	—	0·5– 3·8	0·8– 3·0	3·8	5·3
Lime . . .	5·3	6·7–10·1	2·8– 4·2	1·3– 3·8	3·5	8·35
Magnesia . .	8·7	7·8–11·0	6·1– 7·3	6·5– 8·2	7·3	5·9
Oxide of iron .	0·9	0·4– 5·1	trace– 2·1	0·3– 1·3	0·7	0·1
Sulphuric acid .	—	17·4	1·1– 2·5	0·1– 1·4	1·7	4·0
Silica . .	0·9	1·3	38·5–51·5	39·8–50·0	41·9	43·2
Carbonic acid .	—	—	—	—	—	0·6
Chloride of sodium and potassium .	0·35	1·6– 5·3	0·9– 2·6	0·1–	0·45	—
Phosphoric acid .	49·2	38·5–46·3	18·3–26·5	18·7–29·2	14·5	16·2
Total ash in dry grain . .	2·22	2·14	2·5– 3·8	2·5– 3·3	3·0	3·8

Structure of the Grain of the Oat.

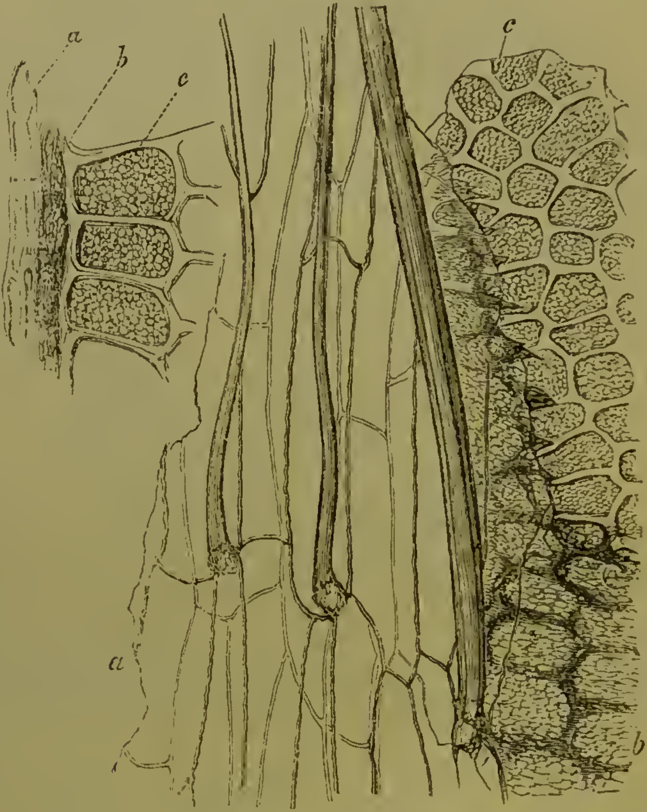
The *membranes* covering the grain of oat, contrasted with those of the other cereals, present several peculiarities.

The *longitudinal* cells forming the outer membrane are disposed in two layers; they are large and well defined, the walls being rather thin and slightly waved; from the upper and outer wall of some of the cells springs a single long and pointed hair, the point being turned towards the summit of the grain; these hairs arise from the cells over the whole surface of the grain, but they become more numerous towards the apex, where they form a beard or tuft, as in wheat.

The *transverse* cells, which may be described as forming the second investing membrane, are disposed in a single layer; their walls are less accurately defined, and they are not very much longer than broad.

The *cells* forming the surface of the seed itself, and which may be described as the third covering of the grain, also consist of a single layer; they are smaller than the corresponding cells of wheat (fig. 79).

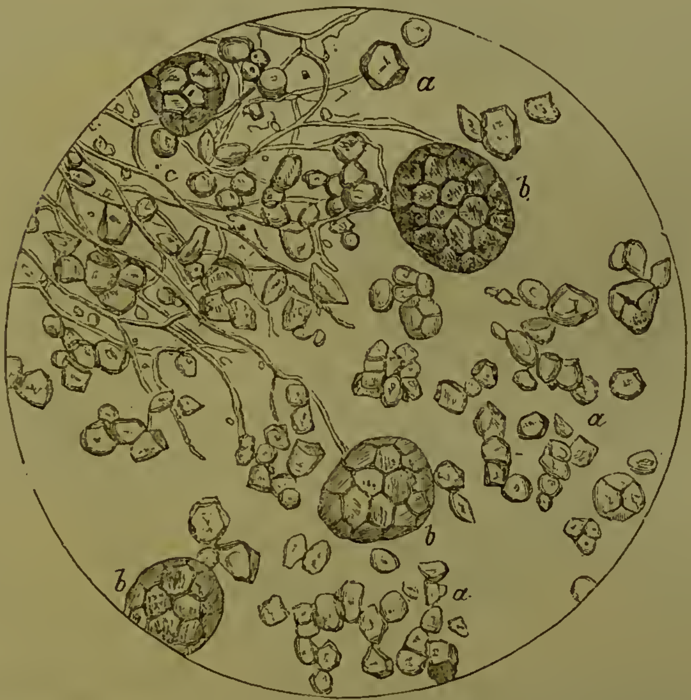
Fig. 79.



Testa of OAT. *a a*, outer; *b b*, middle; and *c c*, inner tunics. Magnified 200 diameters.

The starch granules of the oat present well-marked structural characteristics. They are smaller in size than those of wheat, varying but little in dimensions, are polygonal in figure, without either visible concentric rings or hila, but with central depressions and thickened edges. The great peculiarity of oat starch, however, is, that many of the grains cohere together, forming bodies of a rounded or oval figure, and presenting a reticulated surface, indicative of their compound structure. These bodies escape readily from the cellulose, and, when oat flour is diffused through water, may frequently be seen floating about freely in the liquid. A second peculiarity is, that unlike the other cereal starches, the grains of oat starch, when viewed with polarised light, do not exhibit the usual crosses. The above particulars are well exhibited in the engraving, fig. 80. The walls of the cells of the cellulose are very delicate, and appear, when the cells are emptied of the starch, like threads, as represented in the engraving.

Fig. 80.



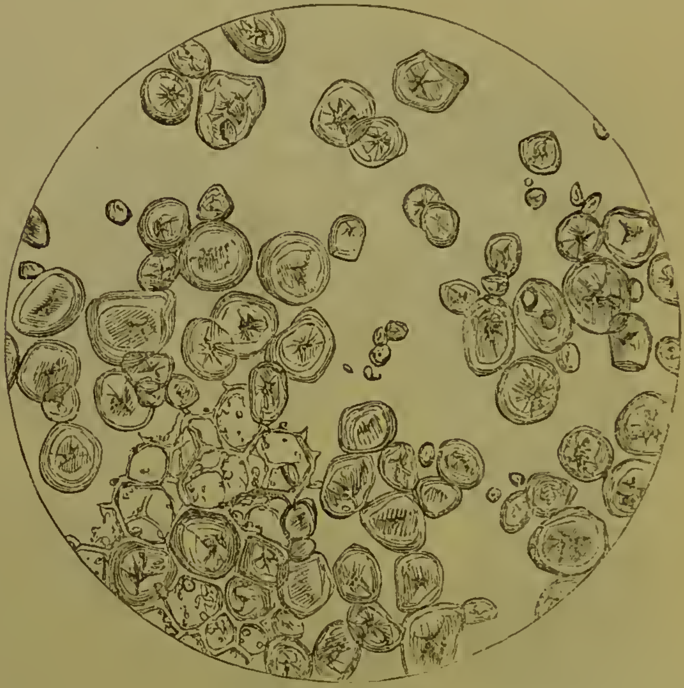
This engraving represents the structure and character of the starch corpuscles of OAT FLOUR, as also of the *cellulose*. Drawn with the Camera Lucida, and magnified 420 diameters.

A figure of oat starch is given in the new edition of Pereira's 'Materia Medica.' In this the larger grains are made fully equal in size to those of wheat starch; whereas they are really several times smaller, as represented in our engraving. This error has probably arisen from the artist having mistaken the compound bodies in question for single granules. The same error pervades some of the measurements given.

INDIAN CORN FLOUR.

Zea Mays, or Indian corn, is met with in the state of flour, in the shops, under the name of '*Polenta*:' it enters into the dietary of many of our public institutions and charities, and is much used in the New World.

Fig. 81.



This engraving represents the structure and characters of the starch granules of INDIAN CORN FLOUR, including the *cellulose*. Drawn with the Camera Lucida, and magnified 420 diameters.

The amount of azotised constituents is less in maize than wheat. When washed with water it does not leave any glutinous residue like wheat, and is said by Gorham to contain a reddish nitrogenous substance to which he has given the name of *Zeïne*. It contains, however, a large quantity of oil, which accounts for its fattening properties.

The starch separated from all the other constituents of the grain forms an important article of diet, which is sold under the name '*Corn flour*,' and which resembles dietetically and chemically an arrowroot.

In those unaccustomed to its use, maize is considered to excite and to keep up a tendency to diarrhœa.

Analyses of Maize.

	Polson. Air-dried. 4 samples.	Poggiale. Dried at 120° C. Mean of samples.	Payen. Dried at 100° C.
Starch . . .	50·1–54·8	64·5	71·2
Fat	4·4– 4·7	6·7	9·0
Cellulose . . .	14·9–20·4	4·0	5·9
Gum and sugar .	2·3– 2·9	—	0·4
Nitrogenous matter	8·7– 8·9	9·9	12·3
Ash . . .	1·6– 1·8	1·4	1·2
Water . . .	11·5–13·2	13·5	—

Ash of Maize.

	Fromberg.	Letellier.
Potash	26·63 }	30·8
Soda	7·54 }	
Lime	1·59	1·3
Magnesia	15·44	17·0
Phosphoric acid	39·65	50·0
Sulphuric acid	5·54	—
Silica	2·09	0·8
Oxide of iron	0·60	—
Loss	0·92	0·1
	100·00	100·00

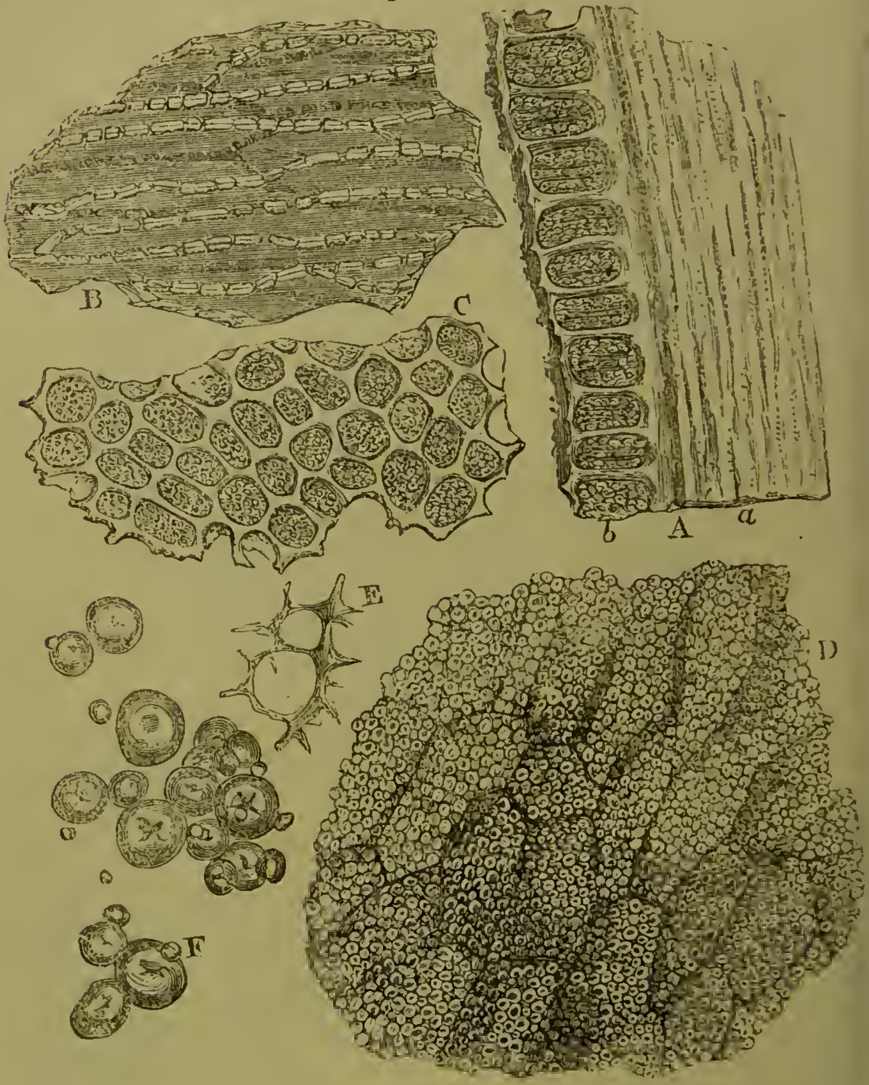
Ash of Maize.

	Way and Ogston. Forty-day.	Graham, Stenhouse, and Campbell. Unknown variety.
Potash	28·4	30·7
Soda	1·7	—
Lime	0·6	3·1
Magnesia	13·6	14·7
Oxide of iron	0·5	0·8
Sulphuric acid	trace	4·1
Silica	1·55	1·8
Carbonic acid	—	—
Phosphoric acid	53·7	44·5
Chloride of sodium . . .	—	0·5
Ash in dried grain . . .	1·5	—

Structure of the Grain of Indian Corn.

The testa of the grain of Indian corn is made up of two membranes; the *outer* of these consists of some seven or eight layers of cells, all

Fig. 82.



A, transverse section of *testa* of Indian Corn. B, longitudinal view of cells of outer layer of testa; C, cells of *surface* of grain; D, cells of its *substance*; E, *blastema*; F, starch granules. A 100, B C 200, D 100, E F 500 diameters.

running in one direction, and about three times as long as broad; the margins of the outermost layer are beaded, the beadings being remarkable for a certain squareness of outline.

The *inner* membrane forms the surface of the seed proper, and consists of a single layer of cells resembling those of the other cereals (fig. 82).

The *cells* of the cellulose are very angular, like those of rice, but they differ in being subdivided by numerous septa, forming a cellulated network or blastema, each space enclosing a separate starch corpuscle.

The starch corpuscles of Indian corn bear considerable resemblance to those of the oat; like them, they are somewhat polygonal in outline, and present well-marked central depressions, as well as occasionally a divided and radiate hilum; they differ, however, in their much larger size, in not forming compound bodies, and in presenting under the polariscope well-defined crosses. The central depression appears to be a character common to nearly all the starch granules of the cereal grasses. This depression, combined with the disc-like form of the grains, gives them a general resemblance to the blood discs of the mammalia. In those instances in which the grains, as in wheat and barley, are curved upon themselves, the depression exists of course only on one side of the disc.

RICE FLOUR.

The seeds of rice, *Oriza sativa,* contain a much less proportion of nitrogenised compounds than the other cereal grains, and particularly wheat, namely about 7 per cent. The quantity of fatty matter is also less.

The nitrogenous substance obtained from rice, precipitable by acetic acid, 'has a creamy consistence, an agreeable smell, and a bland taste.'

Much difference of opinion has prevailed in reference to the value of rice as an article of diet, some persons placing it very high. Analysis, however, clearly proves that it is the least nutritious of the cereal grasses; while it usually contains 7 or 8 per cent. of gluten, wheat flour rarely furnishes less than 12 per cent.; again, when cooked, rice swells up greatly and imbibes a very large quantity of water, boiled rice containing about 77 per cent. of moisture. This renders it necessary that a large bulk of cooked rice should be eaten to constitute a sufficient meal.

This difference of opinion has probably arisen from the fact that rice is seldom eaten by itself, but is partaken of frequently with milk, butter, or sugar, the nutritious properties of which substances increase greatly those of the rice itself.

Analyses of Rice.

	Polson. Air-dried.	Poggiale. Dried at 100° C.	Payen. Dried at 100° C.
Starch	78·8	74·5	86·9
Fat	0·1	0·2	0·8
Cellulose	0·2	3·4	3·4
Gum and sugar	1·6	—	0·5
Nitrogenous substance	7·2	7·8	7·5
Ash	0·9	0·3	0·9
Water	9·8	—	—

Ash of Rice.

	Muspratt. Grain.	Muspratt. Husk.	Zedeler.
Potash	18·48	1·60	20·2
Soda	10·67	1·58	2·5
Magnesia	11·69	1·96	4·25
Lime	1·27	1·01	7·2
Phosphoric acid	53·36	1·86	60·2
Sulphuric acid	—	0·92	—
Silica	3·35	89·71	1·4
Oxide of iron	0·45	0·54	—
	99·27	99·18	95·7

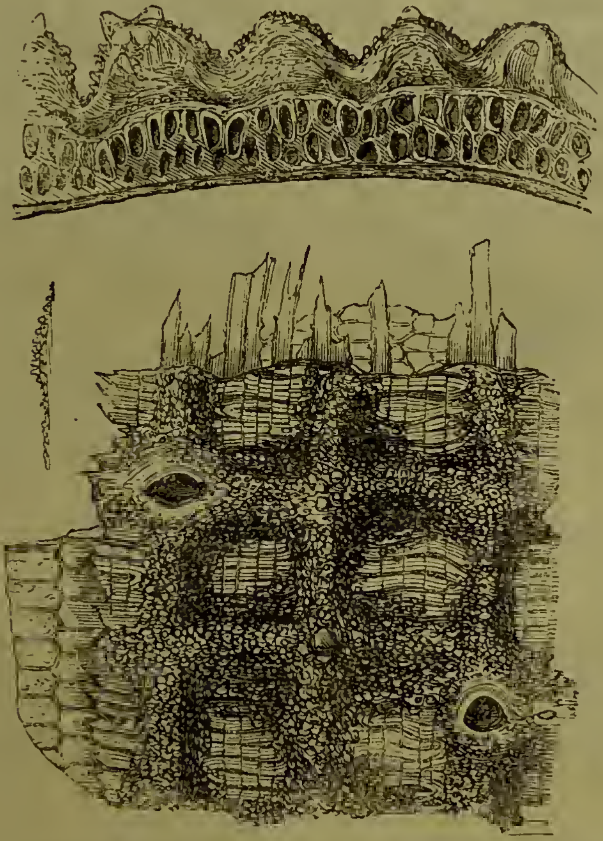
Structure of the Grain of Rice.

The structure of the husk of rice is by no means easy to determine; it is best examined after it has been immersed in glycerine for some time.

The outer surface of the seed is thrown up into ridges, these being arranged both transversely and longitudinally, and describing between them square spaces; the ridges are formed in part of silica in the form of granules; here and there are openings, of somewhat irregular form, and which are the mouths of stomata: the substance of the husk is made up of narrow and rather short fibres; some of these are arranged longitudinally, others transversely; they are brittle, and their edges rough. That they really are fibres is shown by their being hollow, as is seen in transverse sections. Lastly, lying beneath the fibrous membrane is a thin membrane formed of angular cells, rather longer than broad, and the long axis of which is placed transversely. The above description is founded upon the admirable drawing made with the greatest care by Mr. Tuffen West (fig. 83).

The starch corpuscles of rice are small, and for the most part of an angular form, with well-marked central depressions and raised edges; they resemble closely the starch grains of the oat in their polygonal shape, but differ in being much smaller.

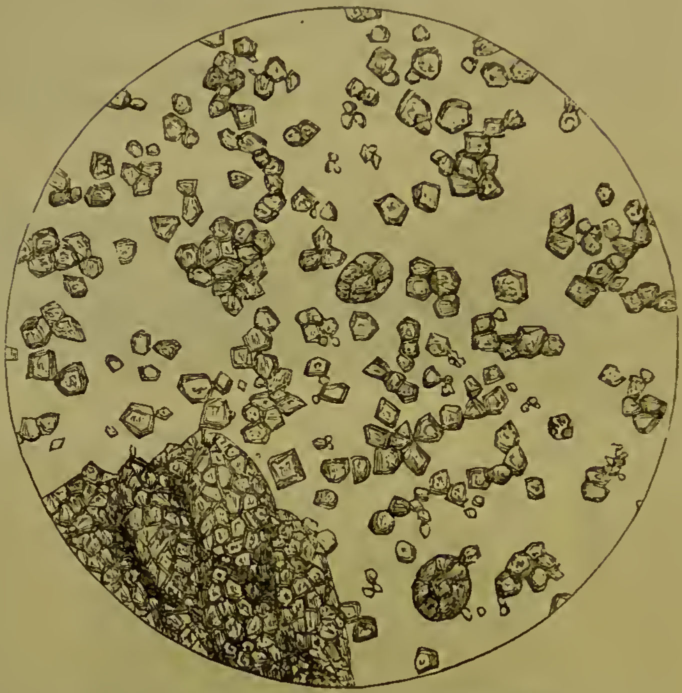
Fig. 83.



Husk of Rice, the upper figure being a transverse section. Magnified 220 diameters.

The cells in which they are enclosed are very angular, and separate readily from each other, in which respects also rice differs from oat flour (fig. 84).

Fig. 84.



This engraving represents the starch corpuscles and cells of RICE. Drawn with the Camera Lucida, and magnified 420 diameters.

But flour and bread are made in different countries from a variety of other grains besides those which have hitherto been described, as *Millet*, of which there are numerous species; *Elusine corocana*, the *Ragee* or *Raggy* of India; *Buckwheat*, which, however, is somewhat poor in astrogenous substances and fat, and the *Gram* of India; *Cicer arietinum*, which made into cakes is palatable and highly nutritious.

COMPOSITION OF THE CHIEF CEREAL GRAINS.

We will now bring this article on 'Flour' to a conclusion by giving some mean analyses of the chief cereal grains and their ashes, which will enable us readily to compare the one kind of grain with the other.

100 parts.	Starch.	Gluten and other azotised matters.	Dextrin, Glucose, or other congenerous substances.	Fatty matters.	Cellulose.	Silica, Phosphates of Lime, Magnesia, and soluble Salts of Potash and Soda.
Wheat, hard, of Venezuela . .	58·12	22·75	9·50	2·61	4·0	3·02
Wheat, hard, of Africa	64·57	19·50	7·60	2·12	3·50	2·71
Wheat, hard, of Taganrog . .	63·30	20·00	8·0	2·25	3·60	2·85
Wheat, demi-hard, of Brie, France	68·65	16·25	7·0	1·95	3·40	2·75
Wheat, White Tuzelle	75·35	11·20	6·05	1·87	3·0	2·12
Rye	65·65	13·15	1·2	2·15	4·10	2·60
Barley . . .	65·43	13·96	1·0	2·76	4·75	3·10
Oats	60·59	14·39	9·25	5·50	7·06	3·25
Maize . . .	67·55	12·50	4·0	8·08	5·90	1·25
Rice	89·15	7·05	1·0	0·80	3·0	0·90

The next table represents the mean composition of the ash of the chief cereal grains. It is taken from Pereira's 'Materia Medica,' and is drawn up from the calculated means contained in Johnston's 'Lectures on Agricutural Chemistry and Geology,' 2nd ed. 1847.

	Wheat.	Barley with Husk.	Oats.	Rye.	Indian Corn.	Rice.
Potash . . .	23·72	13·64	26·18	22·08	32·48	18·48
Soda . . .	9·05	8·14		11·67		10·67
Lime . . .	2·81	2·62	5·95	4·93	1·44	1·27
Magnesia . .	12·03	7·46	9·95	10·35	16·22	11·69
Oxide of iron .	0·67	1·48	0·40	1·36	0·30	0·45
Phosphoric acid .	49·81	38·96	43·84	49·55	44·87	53·36
Sulphuric acid .	0·24	0·10	10·45	0·98	2·77	—
Chlorine . .	—	0·04	0·26	—	0·18	0·27
Silica . . .	1·17	27·10	2·67	0·43	1·44	3·35
Alumina . .	—	0·21	0·06	—	—	—
	99·50	99·75	99·76	101·35	99·70	99·54
Percentage of ash .	about 2·0	2·84	2·18	2·425	about 1·5	1·00

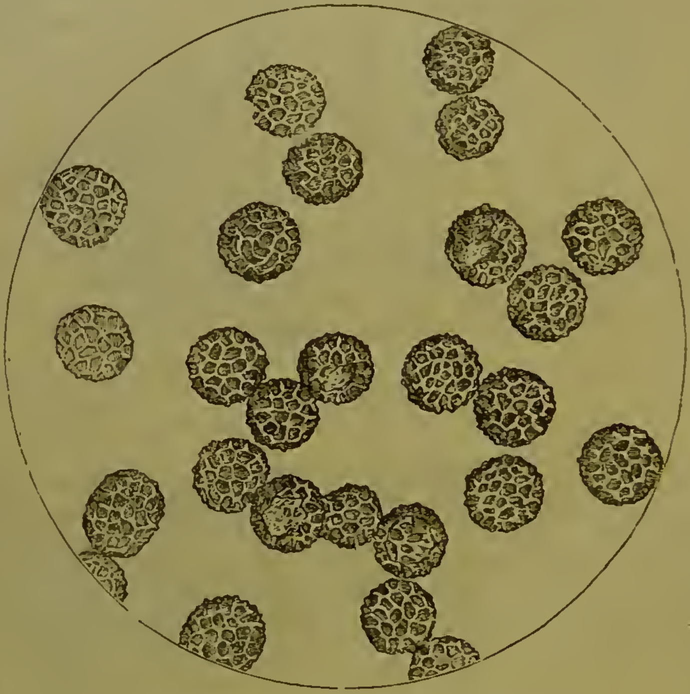
Messrs. Ogston and Way give the following as the percentages of silica in the ash of the ordinary cereal grains: 2·05 to 5·46 silica for wheat; from 23·6 to 70·77 for barley; from 38·48 to 50·03 for oats; and 9·22 for rye.

ON THE PARASITIC DISEASES OF THE CEREAL GRAINS.

The cereal grains and the flours made from them are liable to be infested and deteriorated by the presence of various parasitic productions, both vegetable and animal. As flours thus diseased are sometimes referred to the analyst under the impression that they are adulterated, it becomes necessary that he should be possessed of some information respecting the diseases of the cereal grains.

The principal diseases of grain arising from the attacks of fungi are *ergot*, *smut* or *dust*, *brand*, *rust*, and *mildew*.

Fig. 85.



This engraving represents the spores of UREDO CARIES, magnified 420 diameters. Drawing made from a preparation belonging to the late Dr. Pereira.

ON BUNT, SMUT BOLLS, OR PEPPER BRAND.

(*Uredo caries*, Dec.; *Uredo fœtida*, Bauer.)

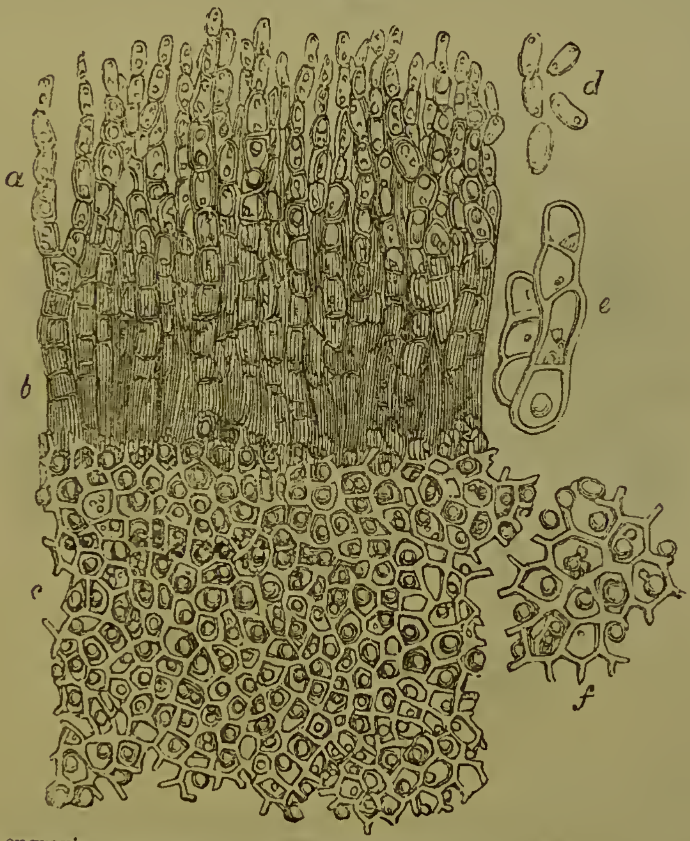
This fungus has hitherto been met with only in the grains of wheat it is easily recognised by its disgusting smell. The spores or sporangia analogous to seed vessels, are large and reticulated, as represented i the figure. Some doubt exists whether this fungus is deleterious or not; by many it is considered to be so. Flour containing it is frequently used for gingerbread (fig. 85).

ERGOT.

(Oidium arbortifaciens.)

Ergot is particularly prone to attack rye: it does not confine its ravages to that one grass, but has been observed to attack a variety of species; and amongst the rest, the ears of wheat.

Fig 86.



This engraving represents a transverse section of Ergot of Rye. *a.* Terminal colourless filaments bearing the spores, which are seen on the extremities. *b.* The coloured threads which constitute the black or purple portion of the grain. *c.* The cells, with the contained spherules of oil, which form the body or colourless part of the grain, magnified 420 diameters. *d, e, f,* represent minute portions of the same structures, more highly magnified—viz., 670 diameters.

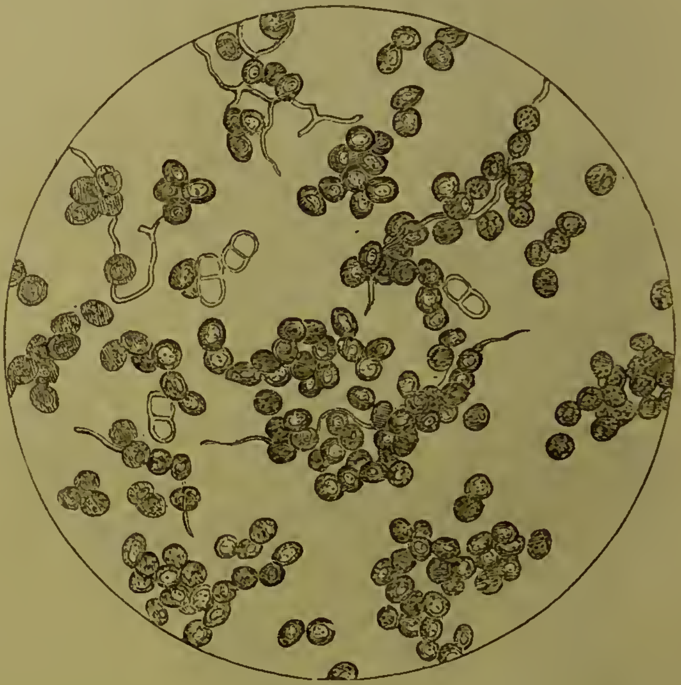
The engraving (fig. 86) represents a section of ergotised rye.

In flour contaminated with ergot the structures above delineated occur, of course, in a much broken and divided state.

Numerous and well-attested instances are on record of dangerous and even fatal effects resulting from the consumption of bread containing ergot.

The active principle of ergot is named *ergotine*. It is obtained by treating ergot with ether to remove fat and wax, afterwards exhausting with boiling alcohol, concentrating the solution, and precipitating by cold water. It is a reddish powder, insoluble in water, ether, and dilute acids, but dissolved by alcohol, strong acetic acid, and caustic potash.

Fig. 87.



This engraving represents the spores of UREDO SEGETUM, magnified 420 diameters. Drawing made from a preparation belonging to Dr. Swayne.

Test for ergot.—Laneau renders the paste of the flour alkaline, adds dilute nitric acid to slight excess and then neutralizes, when a violet-red colour will appear if ergot be present, which changes to rosy red when nitric acid and violet when an alkali is added.

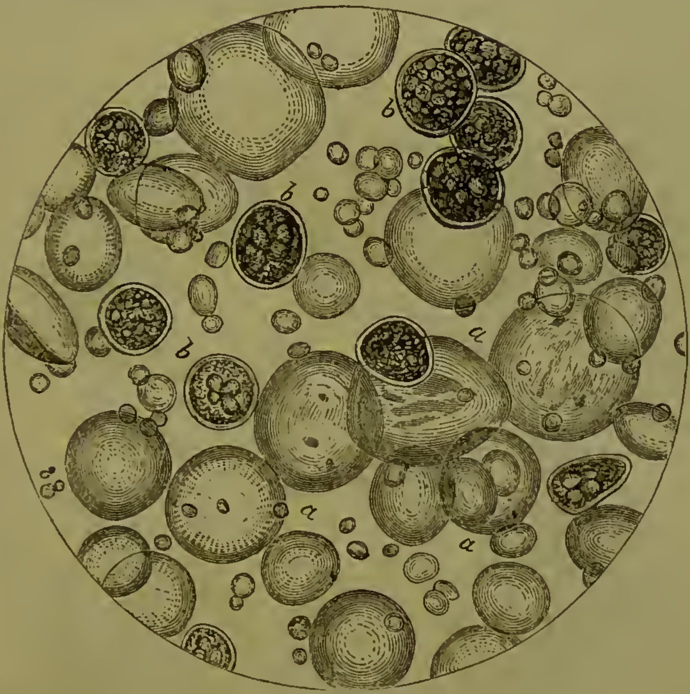
Another test is the odour of propylamin developed on the addition of liquor potassæ to the ergotised flour.

ON RUST, RED-RAG, RED-ROBIN, RED-GUM.

(*Uredo rubigo* and *Uredo linearis.*)

These so-called species are but young states of *Puccinia graminis.* They form yellow, brown, oval spots or blotches upon the stem, leaf, and chaff; the sporules of which the blotches consist are intermediate in size between those of *Uredo caries* and *U. segetum*; they are at first round, afterwards oval, and attached by a pellucid, short, and slender stalk to the surface on which they are developed, but after a time they become free (fig. 87.)

Fig. 88.



WHEAT FLOUR infested with *Puccinia graminis*, in an early stage of development. 420 diameters.

The engraving (fig. 88) represents some wheat flour largely infested with *Puccinia graminis* in the state formerly called *Uredo rubigo.* The sample, which was offered for sale, was brought to Dr. Muspratt, by whom it was forwarded to the author.

ON SMUT, OR DUST BRAND.

(*Uredo segetum.*)

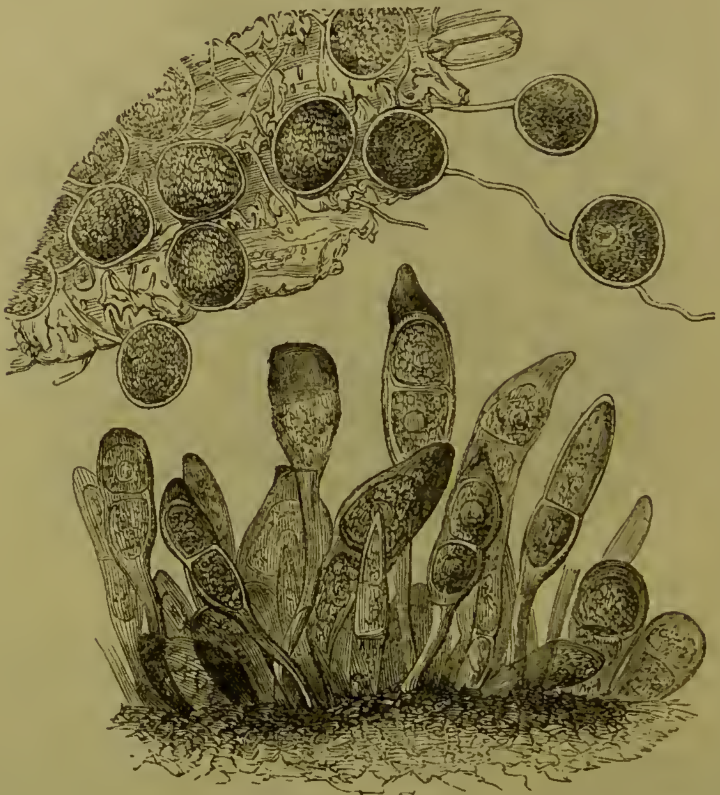
This fungus is comparatively rare in wheat, but very common in barley and oats; rye does not appear to be subject to it. It has not the disagreeable smell of the preceding species, and the spores are several times smaller (fig. 87).

ON MILDEW.

(*Puccinia graminis.*)

The ripe spores of this fungus are dark-brown club-shaped bodies, having the broader end divided into two compartments filled with sporules. ‘I have observed this fungus with the rust fungi in a way

Fig. 89.



PUCCINIA GRAMINIS.

In all stages. Magnified 500 diameters. From specimens kindly furnished by the Rev. Prof. Henslow.

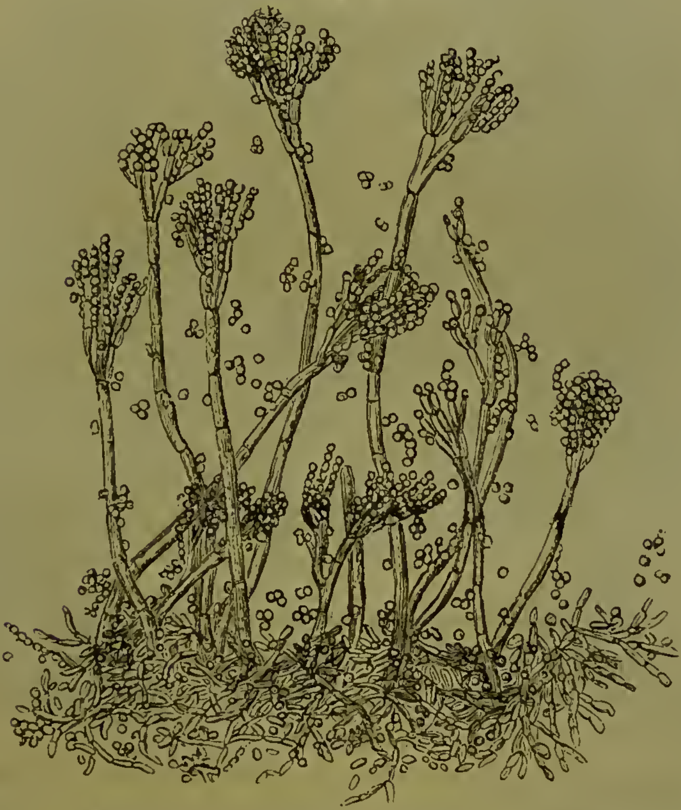
that strengthens my opinion that they are identical.'—*Professor Henslow.*

In the engraving (fig. 89) this fungus is represented in all the stages and conditions of its growth.

Penicillium glaucum, Fermentum cerevisiæ, &c.

When bread has been kept for a few days, and has become stale, certain species of fungi are apt to become developed in it. One of these is the well-known *Penicillium glaucum*, which forms the green mould of cheese and other decaying organic substances: it is described and figured in a memoir by the author contained in the thirty-sixth volume of the 'Medico-Chirurgical Transactions' (fig. 90). Other species of Penicillium according to Parkes are *Penicillium citophilum* and *Penicillium roseum*, of a greenish, brownish, or reddish yellow colour.

Fig. 90.

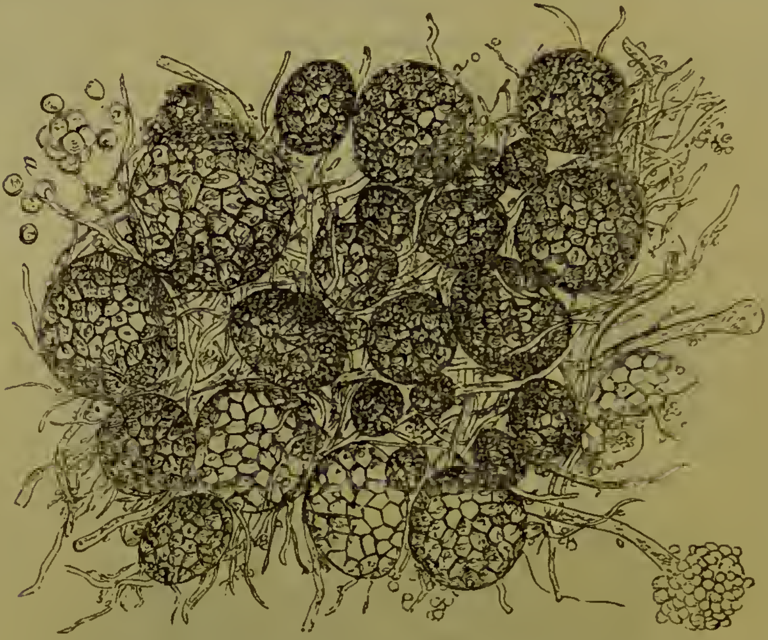


Penicillium glaucum in its perfect state of development.

A second species of fungus is *Fermentum cerevisiæ*, or the yeast fungus, also described and figured in the memoir above alluded to. Its development in bread goes in part to show that the vitality of the yeast is not altogether destroyed by the baking of the bread. It will be described and figured under the head of 'Yeast.'

A third fungus found in stale bread is very different from either of the others; it is represented in the engraving, fig. 91. It is of a bright yellow colour, and it often, from its abundance, causes the bread to assume in patches the same colour. This is the *Oidium orantiacum*.

Fig. 91.



Oidium orantiacum fungus, commonly found in *stale* Bread.

Vibriones.

These also are sometimes found in moist and damaged flour.

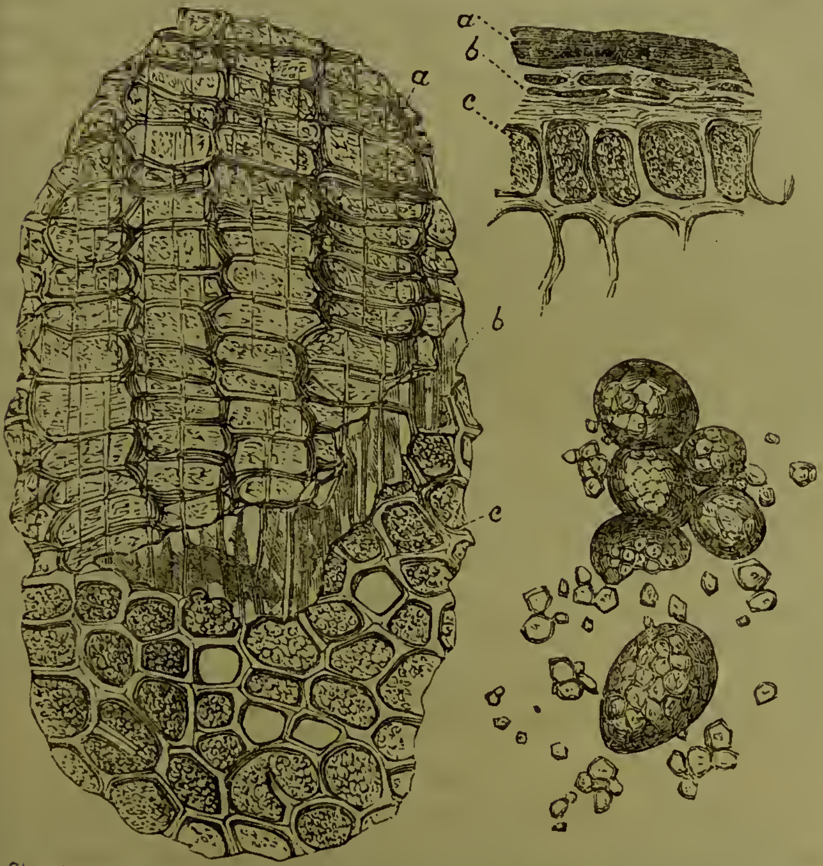
The Bearded or Poisonous Darnel.

The poisonous grass, *Lolium temulentum*, or *darnel*, is by no means of uncommon occurrence, and numerous accidents have from time to time occurred, in consequence of its becoming mixed either with the flour of wheat, or some other cereal farina.

The effects of darnel on man are thus described by Pereira:—

'The ill effects of the seeds of bearded darnel on man were known to the ancient Greeks and Romans. The symptoms which they produce are twofold: those indicating gastro-intestinal irritation,—such as vomiting and colic; and those which arise from disorder of the cerebro-spinal system—such as headache, giddiness, languor, ringing in the ears, confusion of sight, dilated pupil, delirium, heaviness, somnolency, trembling, convulsions, and paralysis. These seeds therefore appear to be acro-narcotic poisons. According to Seeger, one of the most

Fig. 92.



Structure of the grain of Lolium temulentum, or *Darnel*. Showing transverse and vertical sections of testa, magnified 200 diameters; also the characters of the starch corpuscles, magnified 500 diameters.

certain signs of poisoning by them is trembling of the whole body. Both Burghard and Schober (quoted by Wibmer) mention a death having resulted from their use. In Cordier's cases their ill effects were directly ascertained by experiments made upon himself; but n most other cases they were the result of accidental poisoning. In general they have arisen from the intermixture of bearded darnel seeds with other cereal grains. In a prison at Cologne, sixty persons suffered from the use of a bread meal, containing a drachm and a half of *Lolium temulentum* in six ounces of meal.

As the chemical tests for darnel when mixed with flour are not very satisfactory or decisive, we have submitted the seeds to microscopical examination, and find them to be so different from those of wheat or rye, that when admixed with these in the state of flour they may be readily detected.

The starch corpuscles resemble very closely those of rice in form—that is, they are polygonal—but they are much smaller, and, like those of the oat, they are frequently united into compound grains of various sizes, the larger grains consisting of some fifty or sixty starch corpuscles.

The structure of the *testa* is very different from that of either rice, the oat, or indeed any of the other cereal grains: it is formed of three coats or membranes; the cells of the *outer* coat form but a single layer, and contrary to the arrangement which exists in the oat, their long axes are disposed transversely, in which respect they resemble rice: the fibres of the husk of rice and the cells of the testa of *Lolium* are, however, very distinct in other respects. In the former the cells are long and narrow, forming fibres, while in the latter they are but between two and three times as long and broad.

The cells of the *second* coat, which are ranged in two layers, follow a vertical disposition—an arrangement which is contrary to that which obtains in all the other cereal grains with the exception of rice.

The cells of the *third* coat form but a single layer, and resemble those of the other grains described (fig. 92).

Lolium is said to be best detected apart from the microscope by means of alcohol, which gives a greenish solution of a disagreeable taste, and which on evaporation leaves a resinous yellowish green extract.

We have now to consider the diseases of corn produced not by the invasion of parasitic fungi, but animal productions.

THE WEEVIL.

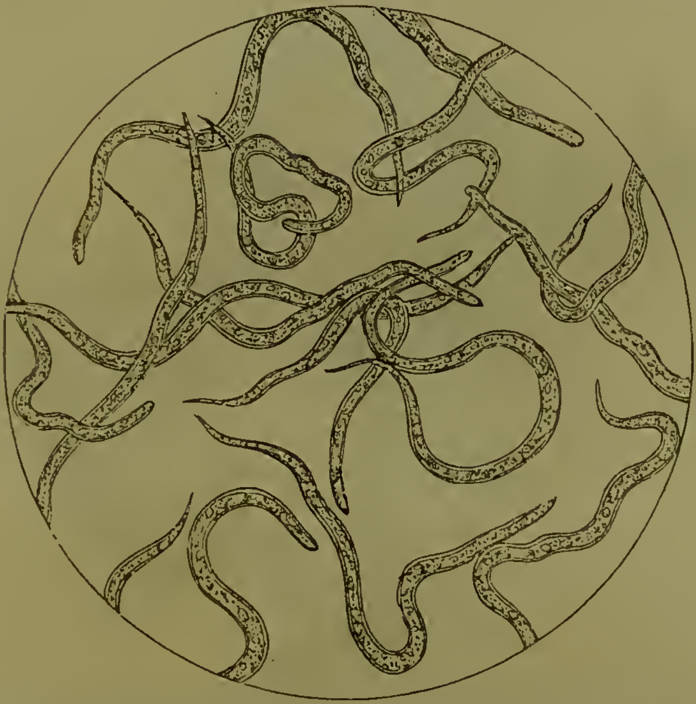
The Weevil, *Calandra granaria*, is of frequent occurrence in grain and flour which have become damaged. The presence of the weevil in the grain is revealed by the existence of a little hole visible on the surface of the grain. If the grain be crushed it will be found to consist chiefly of a shell with the starch eaten away. It is of much more frequent occurrence in the grain than in the flour.

ON EAR COCKLE, PURPLES, OR PEPPERCORN.

(*Vibrio tritici.*)

The grains affected turn green at first, and ultimately black; they become rounded, resembling a small peppercorn; the husks are spread out and the awns twisted, by which means the infected ears are readily observable amongst the standing corn. The blighted grains are filled with a moist cotton-like substance and contain no flour. This substance is composed of myriads of eel-shaped animalcules, which, as soon as moistened with water, exhibit the most active movements (fig. 93). A most extraordinary circumstance connected with these animalcules is, that they may be so perfectly dried that on the slightest touch they break up into powder, and yet, when moistened, they will revive, and become as active as at first. This operation may even be repeated several times before the vitality of the animalcules is finally destroyed.

Fig. 93.



Serous VIBRIO TRITICI, magnified 100 diameters. Drawing made from preparation belonging to the late Dr. Pereira.

ON THE WHEAT MIDGE.

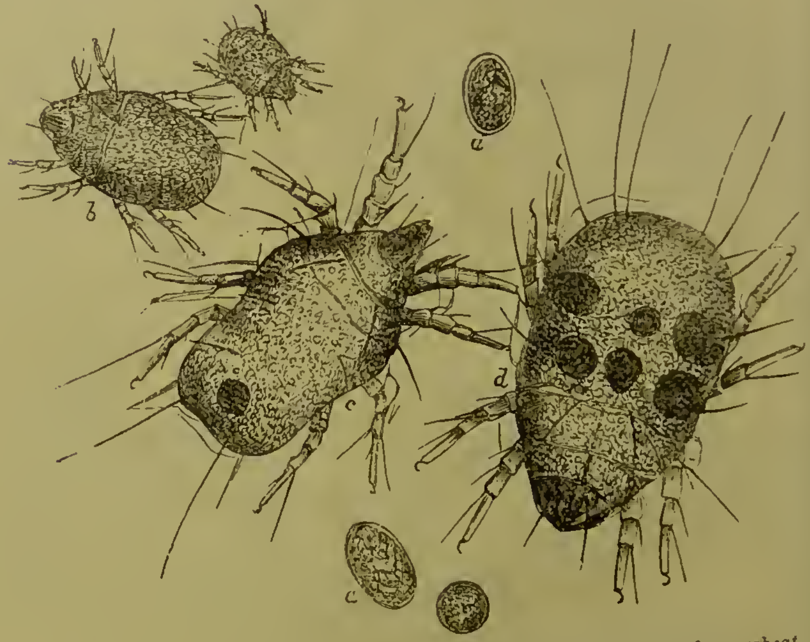
(*Cecidomyia tritici.*)

This is a two-winged fly, which may be seen in myriads in the early part of June, in the evenings from seven to nine o'clock, flying about the wheat for the purpose of depositing its eggs within the blossoms; the eggs become hatched into yellow maggots or caterpillars, and by these the mischief is occasioned; they cause the nondevelopment of the ovary, so that the grain never advances beyond its condition at the time the flower first expands. All the grains in an ear are not usually affected, but only grains here and there. A figure of the fly and its caterpillar will be found in the 'Transactions of the Linnæan Society.'

ACARUS FARINÆ.

This mite is never present in flour unless this has become damaged. It differs considerably in structure from the sugar mite (fig. 94).

Fig. 94.



Acarus Farinæ, or *meal mite*, from the ovum to the mature state, from *wheat flour*. *a a, ova*; *b b, young*; *c, male*; *d, female*. Magnified 75 diameters.

Another species of acarus, met with on one occasion in wheat flour, is exhibited in the engraving, fig. 95.

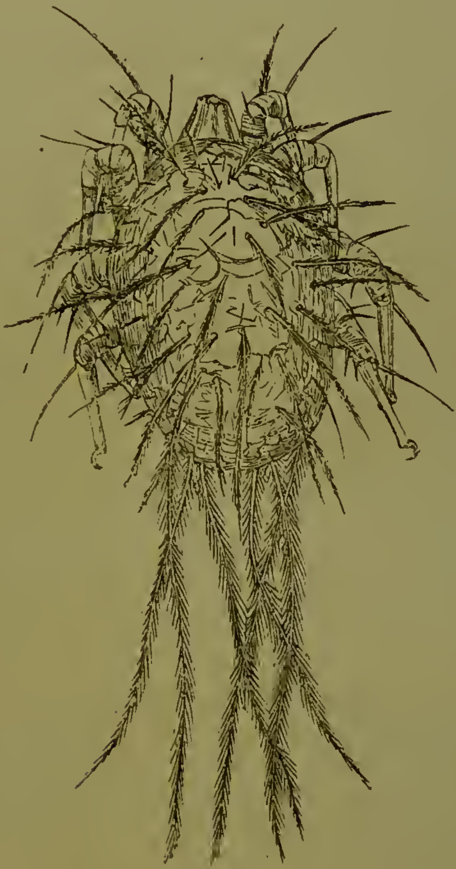
THE ADULTERATIONS OF FLOUR.

The adulterations to which flour is subject are of two kinds, and consist in the addition of either vegetable or mineral substances.

The principal additions coming under the first head, which are made to flour, are with various descriptions of other kinds of flour and meal.

One adulteration of flour is with *bean meal*. It is a common practice for millers to add bean meal to flour; and it is said that this addition is not made so much for the sake of profit, as to render certain descriptions of flour more tenacious when made into dough, bean meal effecting this object in consequence of the large quantity of glutinous matter which it contains. In the case of genuine wheat flour of good quality, no such addition is required; when the flour is damaged, beans are used in considerable quantities.

Fig. 95.



ACARUS from flour. Drawn with the Camera Lucida, and magnified 220 diameters.

Another addition sometimes made is *rice flour*. The purpose served by the addition of this article, unless it be exclusively for the sake of adulteration, is not apparent, since it does not make bread to bind better. It is said indeed to cause it to hold more water, and it possibly has some effect in whitening it.

Again, in some cases, *barley, rye, Indian corn*, and *potato* flours have been added to wheat flour.

According to the evidence of Mr. Emerson, the manager of 'The People's Flour Mill,' at Leeds, given before the Parliamentary Committee on Adulteration in 1855, wheat flour is frequently adulterated with about twenty-five per cent. of *barley flour*, which is not much more than half the price of wheat flour.

The following very curious evidence, in regard to the adulteration of wheat flour, was given before the Committee above referred to by Mr. Potto Brown, a miller of forty years' standing, and whose business was chiefly in London:—

'Barley is mixed with wheat in some districts to cheapen the price. In other districts wheat is mixed with barley to improve the quality, particularly in Northamptonshire. The poor people consider barley more nutritious than wheat flour. I do not know that that is the case; I am doubtful of the point, but it is the universal opinion of the poor people.'

Again: 'To give the above qualities to my flour, I add one part of bean flour to sixty parts of wheat meal; never more than one in forty.

'White *peas* improve the appearance of flour, but not the quality, and are put in to cheapen it.'

Sir J. Gordon, mayor of Cork, furnished the Committee with the following evidence in regard to the use of Dari:—

'There is an Egyptian grain called Dari, that was imported in very large quantities at one time into Cork; that to a moral certainty was for the purpose of mixing with wheaten flour: they were able to sell that for 6*l.* a ton, while the other was bringing nearly three times that amount.'

The Adulterations of Cones Flour.

There is an article in common and daily use by bakers, denominated *'Cones'* or *'Cones flour.'*

Dr. Paley, of Peterborough, brought the author a sample of flour for examination, seized on suspicion, and which he stated the baker called 'Cones Flour.' On subjecting this to microscopical examination, it was found that it consisted entirely of rice flour.

This led to further enquiries. The author soon learned that genuine cones flour consists of the flour of a particular species of wheat called *Revet.*

Further, that it was employed by bakers to dust the dough, as well as the boards upon which this is made into loaves, the object of its use being to prevent the dough either adhering to the boards, or the loaves to each other, in the course of baking.

Having learned thus much, the author procured from bakers numerous samples of cones, and subjected them to examination; and twenty-two samples of cones were thus examined with the microscope, from which it appeared that five of the samples were genuine, and consisted of wheat flour, and that the other samples were mixtures, sometimes without any wheat flour at all, of rye, rice, bean and Indian corn flour, the rice flour being the most frequent constituent.

In fact, *Cones flour is rarely to be obtained genuine, but is subject to an enormous amount of adulteration*; this usually consisting in the addition of very large quantities of *rice, rye, barley, bean,* and *Indian corn* flours, and sometimes of *salt* and *alum.* Some of the samples did *not contain a particle of wheat flour*, of which alone they should consist.

The object of these additions is obviously to cheapen the article; and that this purpose is effected sometimes to the extent of nearly one-half might be readily proved by quoting the several market prices of the different varieties of grain above referred to.

That this is really the object may be shown in another way: several qualities of cones flour are sold, the best being nearly twice the price of the worst, and the adulteration being usually in proportion to the price.

Two questions now present themselves for consideration in connection with cones flour: the first is, whether any real necessity exists for the use of even genuine, much less adulterated cones flour; and the second is, whether this flour, especially when adulterated, as it usually is, is ever applied to any other purpose than that avowed.

The first question is almost sufficiently answered by the fact that some do not use cones flour at all, and yet do not experience any great difficulty in the manufacture of the bread; there is therefore good reason for believing that price has very much to do with the general employment of cones flour, even in those cases in which it is really used to prevent the adhesion of the loaves.

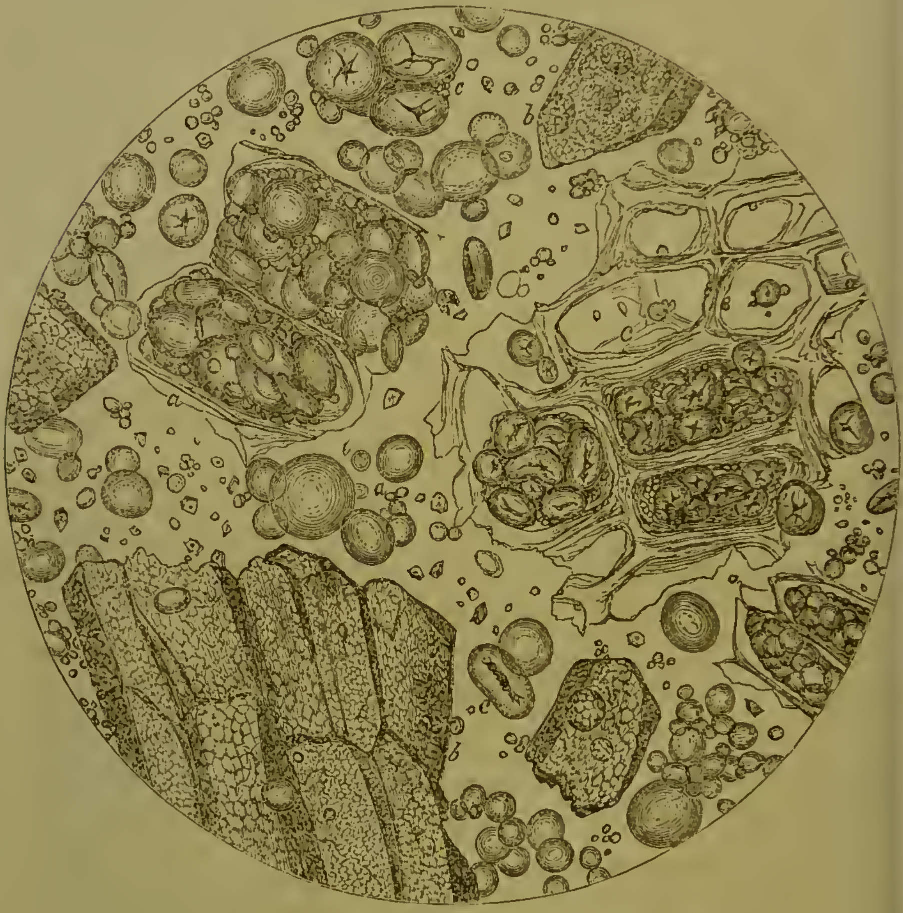
With regard to the second question, there can be no doubt but that cones flour is frequently employed in the adulteration of bread: this is shown in some cases by the character of certain of the adulterations to which it is subject, namely those by admixture with bean flour, alum, and salt. Now bean flour is actually of a more glutinous and adhering nature than pure wheat flour of good quality, and therefore its presence tends to unfit it for the very purpose for which it is alleged that it is designed.

But some bakers have even acknowledged to the employment of cones flour for the purpose of adulteration, for which, from its composition, especially when adulterated, as it constantly is, it is so well suited.

Supposing, however, the cones flour to be employed for dusting the dough, and that this is a legitimate use, still this does not justify its adulteration.

In the article cones flour, prepared by millers, bakers, then, are furnished with a material avowedly wheat flour, but which, consisting of mixtures of different and cheaper flours, is in every way suited for the adulteration of bread; and that it is extensively used for this purpose cannot be doubted. The system adopted by millers, of supplying, under the names of cones flour and wheat flour, compounds adapted for adulteration, is surely very cunningly devised. The public know nothing of this article, the master bakers themselves are ignorant of its exact composition; while the journeyman, in most cases, when he adds, by his master's directions, a bushel of cones to a sack of flour, has no idea that he is adulterating the bread.

Fig. 96.



Adulterated CONES FLOUR, consisting of a mixture of *wheat*, *rice*, and *bean* flours. Magnified 225 diameters.

The case of cones flour affords another example of what the microscope is capable of effecting in connection with the subject of adulteration. Had it not been for that instrument, it would have been utterly impossible to have ascertained by scientific means the composition of the heterogeneous mixture called cones flour.

The admirable engraving (fig. 96) exhibits the characters presented by a sample of so-called cones flour, composed of wheat, rice, and bean flours. It is difficult to determine which is the most excellent, the drawing of Mr. Tuffen West or the engraving of Mr. Hart.

'Occasionally in times of famine other vegetable substances are mixed with flour and bread—*chestnuts, acorns*, &c. In 1835, during famine, fatal dysentery appeared in Königsberg, owing to the people mixing their flour with the pollen of the male catkins of the hazelbush. In India the use of a vetch, *Lathyrus sativus* (Kessaree-dholl), with barley or wheat, gives rise to a special paralysis of the legs, when it exceeds one-twelfth part of the flour. The *L. cicera* has the same effect.'—*Parkes.*

Wheat flour, especially that imported from foreign countries, is apt to be contaminated with the farina or flour of a variety of other grains, as of *buckwheat* (*Polygonum fagopyrum*); of *millet*, *Panicum miliaceum; purple cow-wheat* (*Melampyrum arvense*); *Trefoil* (*trifolium arvense*); *Sainfoin or yellow rattle* (*Rhinanthus major*). It does not appear that any of these grains possess injurious properties, although some of them, as the purple cow-wheat, trefoil, and sainfoin impair the colour of the bread made from flour containing any notable proportion of these grains, causing the bread to exhibit a violet, violet-red, or bluish-black colour. For further information in reference to these grains the reader is referred to Parkes' 'Hygiene.'

The Mineral Adulterations of Flour.

Large quantities of *damaged* wheat flour are annually sold: this is usually more adulterated than any other flour, in a variety of ways, to render it saleable; as by admixture with other flours, with *alum*, and *carbonate of soda*. The object of the admixture of alum and soda is to harden the partially decomposed gluten, and to correct the acidity resulting from decomposition.

Alum is frequently added also to sound flour. This is done to cause the bread made from it to appear whiter than it would otherwise do. This addition, like the majority of the adulterations of flour, is practised by millers. A miller who was fined for adulterating his flour with alum had no less than 600 lbs. of that substance on his premises at the time of the discovery.

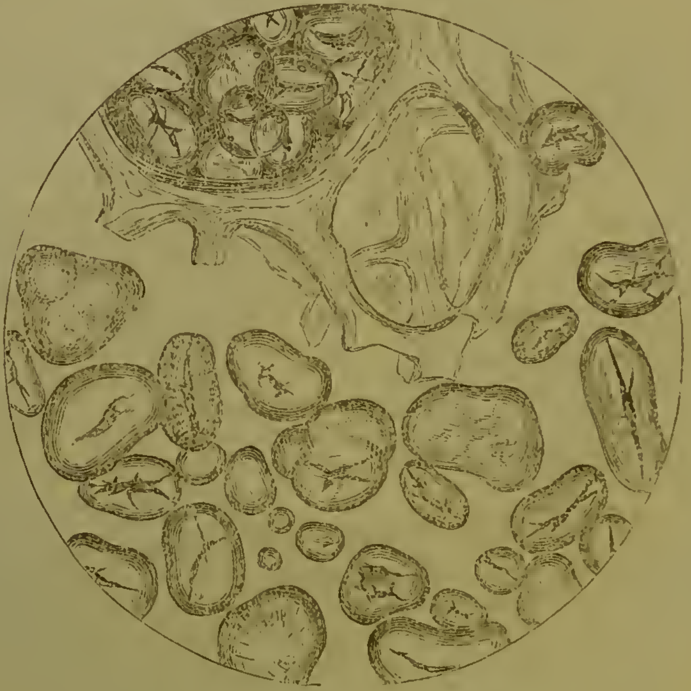
A substance called *mineral white*, which is hydrated sulphate of lime, is occasionally added to flour. Several millers have been convicted for putting this substance into flour.

Convictions have also taken place for using *silicate of alumina*, other names for which are *China clay* and *Cornish clay*.

A variety of other substances, it has been alleged, have been and are used for the adulteration of flour, as *bone ashes, bone dust, white clay* and *chalk*, or *carbonate of lime*; and it is most probable that the majority of them have been thus employed, although we are not ourselves acquainted with any recent cases of their detection in flour. To some of these substances we shall again refer when noticing the adulterations of bread.

The use of another mineral substance, *carbonate of magnesia*, has even been specially recommended by Mr. C. Davy, on the ground that it improves the colour of new and inferior flour, and increases the yield—neither of which results, so far as the public is concerned, are in the least desirable. The increased yield simply signifies *more water*. The quantity of magnesia required varies from 20 to 40 grains to a pound of flour.

Fig. 97.



BEAN FLOUR. Magnified 420 diameters.

THE DETECTION OF THE ADULTERATIONS OF FLOUR.

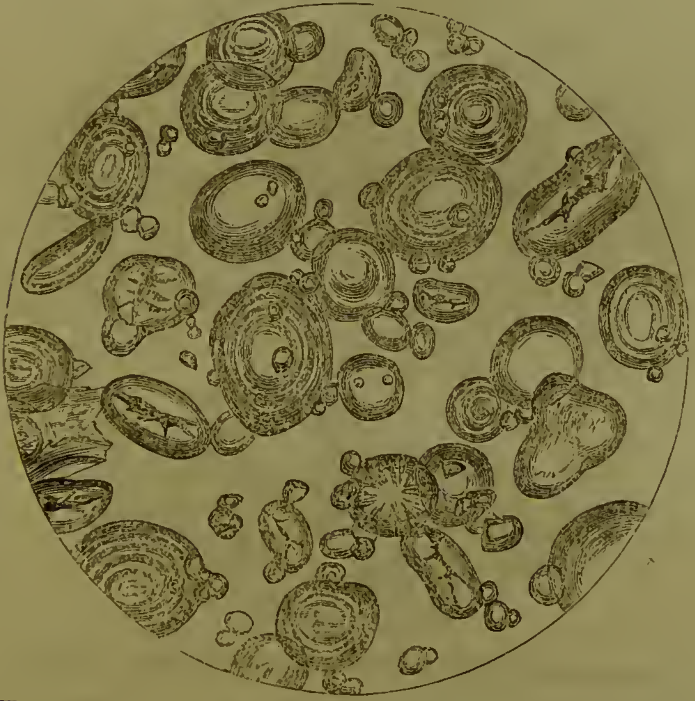
The various substances employed in the adulteration of flour may be divided into *organic* and *inorganic*. Under these heads are included the various articles which have been enumerated in the previous section, 'The Adulterations of Flour.'

Detection of the organic adulterants of flour.—The only means by which the adulteration of wheat flour with the other kinds of flour enumerated can be discovered is by the microscope.

The characters of the starches of the several flours used in the adulteration of wheat flour and bread have already been described, with the exception of potato starch and bean flour.

Bean flour is distinguished from the other flours used by the oval or reniform shape of the granules, the elongated and divided character of the hilum, and the thickness of the walls of the cells enclosing the starch corpuscles (fig. 97).

Fig. 98.



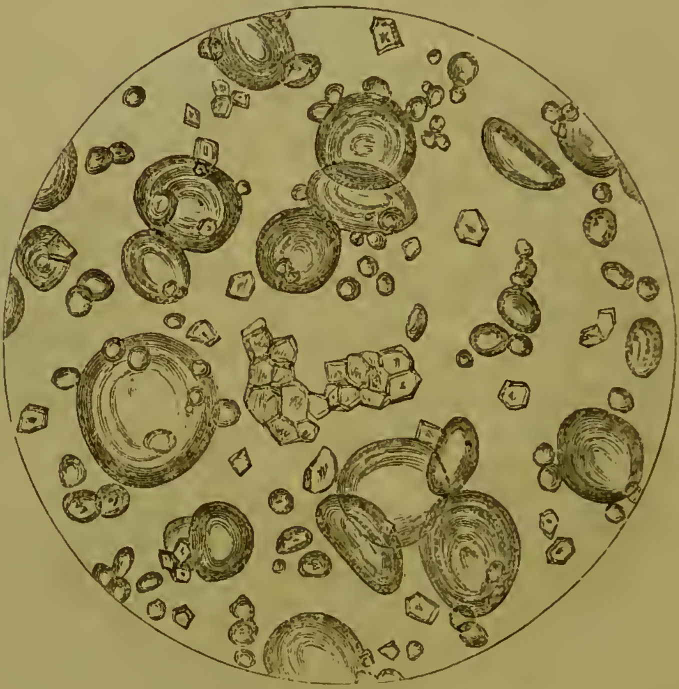
Wheat Flour, adulterated with *bean flour*. Magnified 420 diameters.

Fig. 100 represents the characters of the cells of which the potato is mainly composed, while the starch corpuscles of the potato will be found described and delineated under the head of 'Arrowroot.'

The adulteration of wheat flour with *barley flour* is one by no means easy of discovery when we confine our observations entirely to the form of the starch corpuscles of the two kinds of grain, the differences in the characters of the starch not being very considerable. The corpuscles of barley starch are smaller than those of wheat—especially the more minute granules—and this is nearly the only observable difference. The discrimination may, however, be effected in a very satisfactory manner, by means of the portions of husk present in the flour. The structural peculiarities of the testa and of the cells forming the surface of the grain of wheat and barley have already been pointed out, and to the description of these reference may now be made.

The adulteration of flour with Durra is also discoverable by means of the microscope.

Fig. 99.



WHEAT FLOUR, adulterated with *rice*. Magnified 420 diameters.

On the structure of 'Durra,' Holcus Durra sativus, Forshäl; Sorghum vulgare.—The testa of the grain or seed may be described as consisting of three membranes.

The *outer* is composed of three or four layers of thick-walled cells, rather small, about three times longer than broad, and having the margins finely beaded, somewhat as in capsicum.

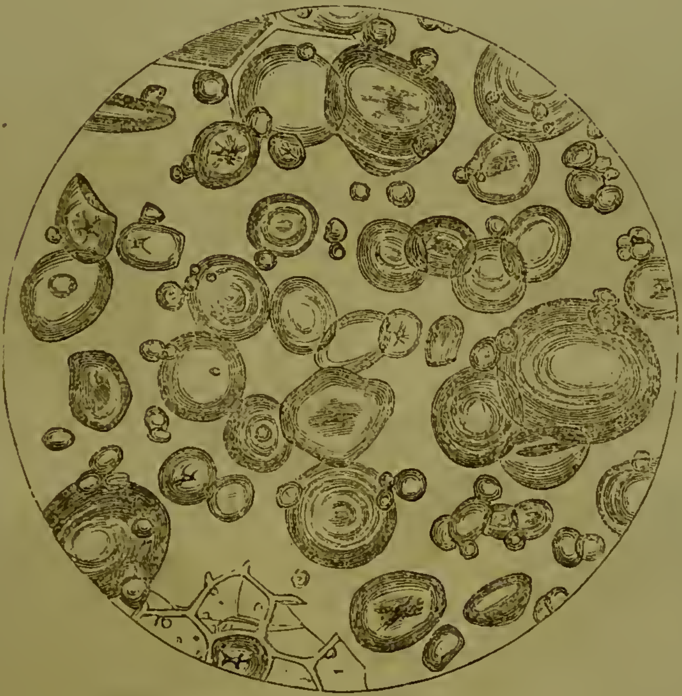
The *middle* coat consists of several layers of cells, with thin walls, and filled with small but angular starch corpuscles.

The *third* tunic resembles that of most of the other seeds of the gramine, and consists of a single layer of angular gluten cells, but which are unusually small.

The substance of the seed resembles very closely that of Indian corn, differing chiefly in the larger size and greater angularity of the starch corpuscles, as well as the stellate character of the hilum (fig. 101).

The last organic adulteration, the method for the discovery of which we have to describe, is that with *bone-dust.* Bone-dust consists of the dust or flour of bones; now bones possess a well-defined structure which is to some extent traceable in the flour; again, bone flour consists in large part of phosphate of lime; this, on the application of nitrate of silver, turns yellow. If, then, on examining any sample of flour with the microscope, we discover minute bony particles, or if, on adding a small quantity of a solution of nitrate of silver to the flour, while under the microscope, particles of a deep and rich golden yellow appear, it is certain that the flour is adulterated with bone-dust. The quantity of bone-dust used must be calculated from the quantity of phosphate of lime contained in the ash of a given quantity of the flour.

Fig. 100.

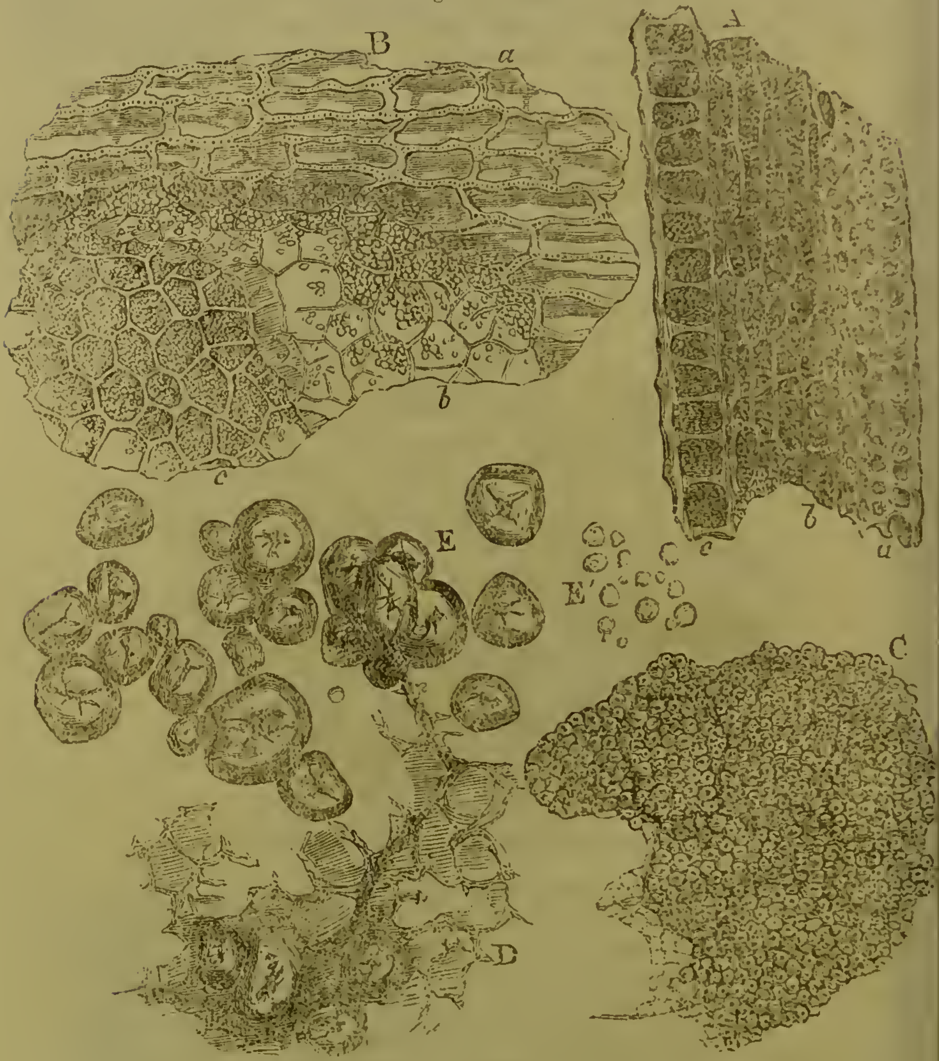


Wheat Flour, adulterated with *Indian Corn flour.* Magnified 420 diameters.

Detection of the inorganic adulterants of flour.—The processes for the detection and estimation of *chalk* or *carbonate of lime, carbonate of* *magnesia, sulphate of lime,* and *soapstone* or *silicate of magnesia, China clay* or *silicate of alumina,* have already been described in the article on 'Tea.'

We have then now only to consider the methods by which *car-*

Fig. 101.



Durra. A, transverse section of testa, * 200. *a*, outer; *b*, middle; *c*, inner coat. B, longitudinal section of testa, * 200. *a*, outer; *b*, middle; *c*, inner tunic. C, * 100, *substance* of seed, showing the large angular cells filled with starch, of which it is composed. D, * 500, parts of large cells, showing the pseudo-cell structure, in which the starch corpuscles are separately lodged. E E, * 500, starch from testa and from substance of grain.

bonate of soda, *alum*, or *sulphate of potash and alumina*, and *sulphate of copper* may be detected and estimated.

The detection of carbonate of soda.—The ash of wheat, and of the other cereal grains, as will be seen from the analyses already given, is itself free from carbonates. If, therefore, the ash exhibits decided effervescence on the addition of an acid, it may be safely assumed that some extraneous carbonate has been added to the flour, most probably carbonate of lime, magnesia, or soda. The soluble portions of the ash should be extracted with water, and the solution evaporated; if now a distinct effervescence is obtained on the addition of an acid, there can be no question but that a carbonate of an alkali has been added, in all probability carbonate of soda, the amount of which, however, must be estimated by the usual alkalimetrical or gravimetrical method.

But if carbonate of soda has been added, the bread itself will be decidedly alkaline to test paper, and again, in those cases in which bread has been adulterated with a considerable quantity of potatoes, the ash will be found to effervesce from the presence of carbonates derived from the destruction of the organic acids present in the potato. The distinction between these two cases is that, where the alkali has been added to the dough, the whole mass of the bread is alkaline, which is not so where the bread has been adulterated with potatoes only.

If no effervescence occur, the carbonate will be found in the insoluble portion of the ash, and will consist, as already stated, of carbonate of lime or magnesia, and here again quantitative determinations will have to be made.

On the detection of alum.—The full details of the more important of the processes employed for the detection and estimation of alum will be found fully described in the article on 'Bread.' They are essentially the same for flour; and since alum is very frequently added not alone to bread but to flour, no examination of the latter article should be considered to be complete which does not include the search for alum.

The detection of sulphate of copper.—Since this salt is but rarely found in flour, and occurs more frequently in bread, we have deemed it best to give the process for its detection also under the head of 'Bread.'

A ready method of detecting the *presence of mineral* substances in flour is given by Redtenbacher. The flour is well shaken up with chloroform; the flour floats on the surface, and the mineral matter falls to the bottom.

CHAPTER XII.

BREAD AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any foreign vegetable or mineral substance, including alum, but not yeast and salt.

THE MANUFACTURE OF BREAD.

The word 'Bread' may be applied not only to the flour of wheat, but to that of any other grain when mixed with water, and rendered light and porous by the action of carbonic acid gas and baked.

Three methods are employed in rendering the dough light: by the use of yeast, of leaven, or by the employment of certain saline substances from which carbonic acid gas is disengaged. In the two former cases the carbonic acid is generated at the expense of the sugar and part of the starch; and in the latter it is simply liberated from a carbonate by the action of an acid.

Hence two kinds of bread are manufactured—that made with yeast or leaven is called *fermented* or *leavened* bread, the other, prepared without leaven, is denominated *unfermented* or *unleavened* bread. The operation of the substances employed in the manufacture of the latter description are to a certain extent analogous to that of yeast.

Leavened bread should consist only of flour, yeast, and water, with a little salt; such is the composition of genuine *home-made bread*, the flavour of which is so agreeable, and so very different from that of ordinary bakers' bread.

In the preparation of cheap bread, flour of inferior quality is frequently used, and this is often mixed up with salt, potatoes, sometimes rice and other flours, and alum; these substances impart to it a taste very distinct from that of home-made bread, and occasion much of the difference observed between that description of bread and ordinary bakers' bread.

The more general method of rendering bread porous is by fermentation, induced either by means of leaven or yeast, which, however, requires to be conducted in a very careful manner, as if not carried far enough the bread will be heavy and sodden; and if too far, acetic and lactic acids and other undesirable products are generated.

The lightest and most porous bread is made with wheat flour, the lightness arising from the peculiar tenacity of the gluten, which causes the dough to retain the carbonic acid more strongly in its interstices.

When flour, in the moist state, is exposed to the air, the nitrogenous matter contained in it undergoes a peculiar decomposition whereby it acts as a ferment, a portion of the starch being converted into dextrin and glucose, and the latter, as well as the glucose originally present in the flour, in its turn is changed into alcohol and carbonic acid.

Now, a portion of dough thus altered is capable of inducing similar changes in a very much larger quantity of sound flour, and hence it is called *leaven*: 'a little leaven leaveneth the whole lump.'

One of the oldest methods of inducing fermentation in flour is by the use of leaven, but its employment is now chiefly confined to the coarser kinds of bread, as the black bread of Germany, but for the finer sorts yeast is now generally used, or a mixture of yeast and leaven.

In this country leaven is rarely, if ever, employed, but almost exclusively yeast in the form of beer yeast, or in the dried state, when it is known by the name of German yeast.

The following is the ordinary method of bread-making pursued:—A certain quantity of potatoes are boiled, peeled, mashed, put into a pail or other suitable vessel, mixed with flour, salt, warm water, and some yeast, and allowed to stand in a warm place. After a time fermentation sets in, and the yeast begins to develope at the expense of the potatoes and flour, till the whole becomes in an active state of fermentation, forming what is technically known as the sponge.

After the lapse of some time the sponge swells up from the generation of carbonic acid, some of the gas coming to the surface and escaping in large bubbles. This goes on for some time, causing an alternate rising and falling of the sponge.

When the sponge is in an active condition fresh portions of flour, salt, and water are added to it. The whole is thoroughly kneaded so as to give rise to an equal liberation of carbonic acid throughout the whole mass. The dough is now allowed to remain at rest for some hours to permit of the further progress of fermentation; it is kneaded a second time, weighed out into loaves, which are again allowed to ferment until they have acquired double the original bulk of the dough, and they are then transferred to the oven to be baked. The heat to which the loaves are subjected quickly arrests fermentation, and causes the expulsion of some of the carbonic acid and alcohol formed. The crumb of a loaf of bread thus prepared consists mainly of water, starch—the granules of which are much increased in size—and gluten; while in the crust the starch is converted into dextrin, and when highly baked both the starch and nitrogenous matters are decomposed, and more or less burned.

'In Paris, where bread-making has been brought to a high degree of perfection, the fermentation is produced chiefly by the gluten of the dough, yeast being used merely to facilitate the action. A lump of dough remaining from the last batch of bread, and consisting of 8 lbs. flour and 4 lbs. water, is left to itself for ten hours; in this state it is called fresh leaven (*levain de chef*). By kneading this with another quantity of 8 lbs. of flour and 4 lbs. water the once-revived leaven (*levain de premier*) is obtained. After another interval of eight hours 16 lbs. of flour and 8 lbs. of water are added, forming the twice-revived leaven (*levain de second*); and after three hours more 100 lbs. of flour and 52 lbs. of water, containing $\frac{1}{4}$ to $\frac{1}{3}$ lb. beer yeast are added, forming the finished leaven (*levain de tout point*). The 200 lbs. leaven thus obtained are mixed after two hours with 132 lbs. of flour and 68 lbs. of water, containing $\frac{1}{2}$ lb. of yeast in suspension and 2 lbs. common salt dissolved. This quantity of dough serves for five or six bakings. For the first baking half the dough, 200 lbs., is made into loaves of the required size and form, which are exposed for awhile in shallow baskets to a temperature of 25° C., equal to 77° F., and then transferred to the oven. The bread thus obtained has a sourish taste and dark colour. The remaining half of the dough is again mixed with 132 lbs. of flour, 70 lbs. of water, $\frac{1}{2}$ lb. of yeast, and the requisite quantity of salt; the half of this quantity of dough is then formed into loaves, left to ferment and bake.

'The same operations are repeated three times, one-half of the dough being each time mixed with 130 lbs. of flour, $1\frac{1}{3}$ lbs. of yeast, and the proper quantity of water and salt. The last stage yields the finest and whitest bread.'—*Watts's Dictionary.*

We will now describe very fully the structure and development of *yeast.*

YEAST, OR THE YEAST-PLANT.

The substance known as yeast is in reality a plant, belonging to the tribe of *fungi*; it consists of a multitude of minute oval or circular bodies or sporules, endowed, under certain favourable circumstances, with extraordinary powers of growth and multiplication.

Three kinds of yeast are employed in the manufacture of bread, viz., brewer's yeast, German yeast, and patent yeast. Some bakers use one and some another, but the greater number make use of patent yeast on account of its cheapness. The fungus is the same species in each.

Brewer's yeast.—This, as is well known, is of a light-brown or fawn colour, and of a frothy consistence; when recent, it is in constant movement, and bubbles of gas escape from it.

Examined with the microscope it is seen to consist of innumerable minute bodies termed sporules, of variable size, some circular and others oval, and all intermingled with very many globules of carbonic acid gas. These sporules multiply rapidly when the yeast is in an active condition.

Brewers and bakers 'distinguish yeast according to the quality of the beer from which it is obtained. *Ale yeast* is the best and strongest, and is used for bread-making. *Porter yeast* is objected to by bakers, but is used in distilleries. *Small beer yeast* is said to be weak but rapid in its effects, and is sometimes used in making rolls.'—*Pereira.*

German yeast.—This, which is sometimes called 'dried yeast,' consists of sporules only, with but little adherent moisture and no gas. It forms a paste-like substance, and is obtained from a fermented liquid by filtration. It is imported into this country principally from Germany, in hempen bags, each holding half a hundredweight. When placed in casks it is apt to burst them, in consequence of the carbonic acid sometimes evolved.

We believe that this yeast is perfectly wholesome, and that no foundation existed for the reports, some time since set on foot, that it possessed injurious properties. It is, however, sometimes adulterated with a considerable quantity of *pipe clay* or silicate of alumina.

The vitality of yeast is destroyed by mechanical injuries, heat, cold, and chemical reagents. Dr. Pereira relates a singular circumstance in reference to the effect of blows on yeast:—

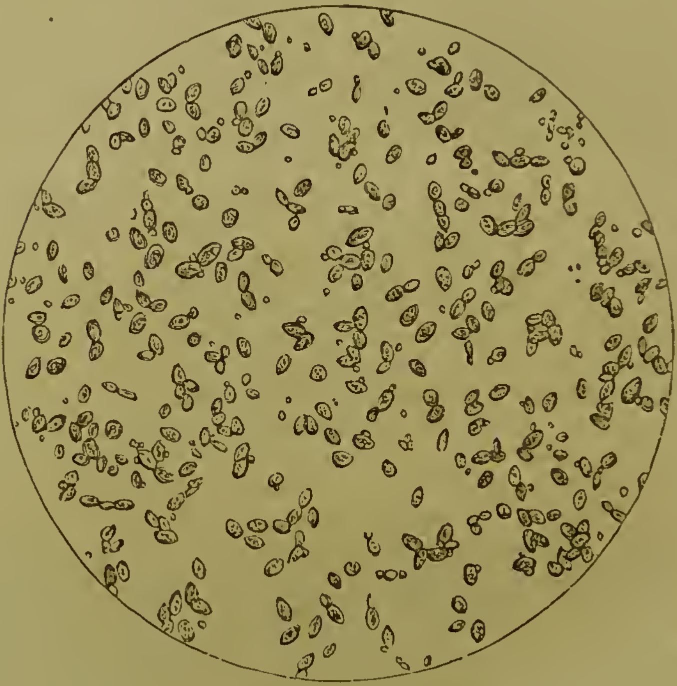
'A very curious fact was mentioned to me by the importer of German and Dutch yeasts in Finch Lane, Cornhill, London. It is that mechanical injury kills or destroys yeast. Foreign yeast is imported in bags, and of these great care is requisite in their removal from place to place. If they be allowed to fall violently on the ground, the yeast is spoiled. A bruise or a blow given to the bag also destroys it. The men who make up the dried yeast into quarter-pound and half-pound balls for sale are obliged to handle it very dexterously or they injure and destroy it. In fact, falls, bruises, and rough handling, kill it, and the yeast which has thus been mechanically injured may be readily distinguished from good unaltered yeast. Its colour becomes darker, somewhat like the change which an apple or pear undergoes when it becomes rotten; and from being crumbly or powdery it becomes soft, glutinous, sticky to the fingers like flour-paste, and even stinks. I have submitted some of this injured or dead yeast to microscopical examination, but have been unable to detect any difference in its appearance from healthy yeast. The effect of mechanical injuries is also noticed by several writers. Thus Liebig remarks that simple pressure diminishes the power of yeast to excite vinous fermentation.'—*Pereira's Materia Medica.*

Patent yeast.—This is prepared from an infusion of malt and hops. It is a thin watery liquid, containing innumerable sporules of the yeast-plant in suspension. The hops are added to prevent the liquid from becoming sour.

This mode of preparation of patent yeast is considerably varied by different bakers. Many add a portion of brewer's or German yeast to an infusion containing either flour or malt with potatoes. These substances supply the food or nourishment upon which the yeast-cells grow and multiply with much rapidity, as well as the material for conversion into carbonic acid. Yeast-cells in the course of a few days make their appearance in a simple infusion of malt, and sometimes even of flour.

Patent yeast, before being mixed with the flour, is often allowed to drain through a copper basin or sieve perforated with numerous holes; by this means the chief part of the mashed potato employed in the preparation of the yeast is separated.

Fig. 102.



This drawing exhibits the sporules of which a sample of Patent Yeast was composed; they differ from the sporules of ordinary yeast in their smaller size, oval form, and in being frequently united in twos and threes; they appear to belong to a distinct fermentation fungus, but their development was not followed out. Drawn with the Camera Lucida, and magnified 220 diameters.

Discovery of the Development of the Yeast-plant.

Few productions have created more interest or excited greater discussion than yeast; its nature and the mode of its operation have been made subjects of keen enquiry and dispute.

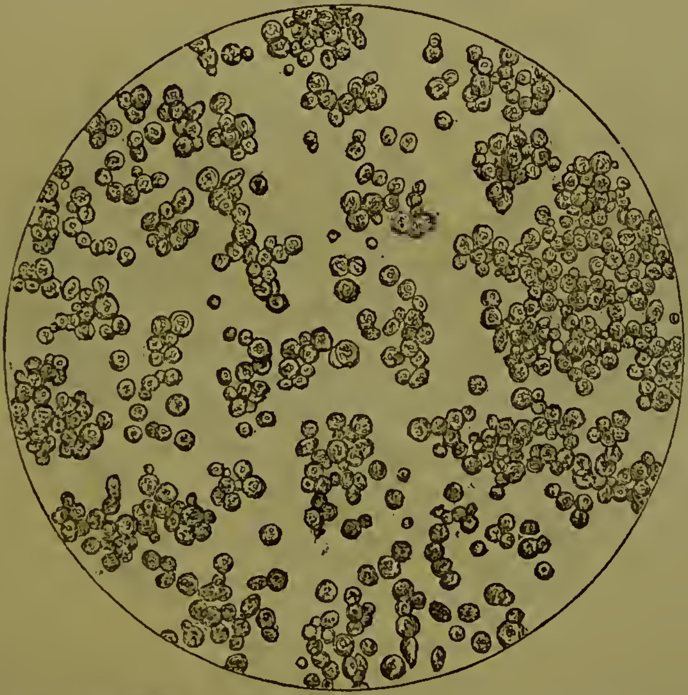
These points are now, however, to a great extent set at rest; its fungoid character is generally admitted, and its *modus operandi* in panification is well understood.

In one particular, however, the history of the yeast-plant was for a long time incomplete: this related to its development.

Most observers admit that the yeast fungus, as met with in the different forms of yeast in use, is in an incomplete state of development, and many, influenced by this conviction, have made attempts to discover the plant in its perfect condition.

Thus Turpin, in the ardour of scientific zeal, spent a whole night in a brewery, with a view to trace out the successive steps in the development of the yeast-plant; and although he has stated that he made out distinctly that the cells or sporules became multiplied by budding, and that they adhered together in twos and even in rows, according to the time which had elapsed after the commencement of germination, yet, as we shall presently see, he failed to discover the yeast fungus in its perfect form.

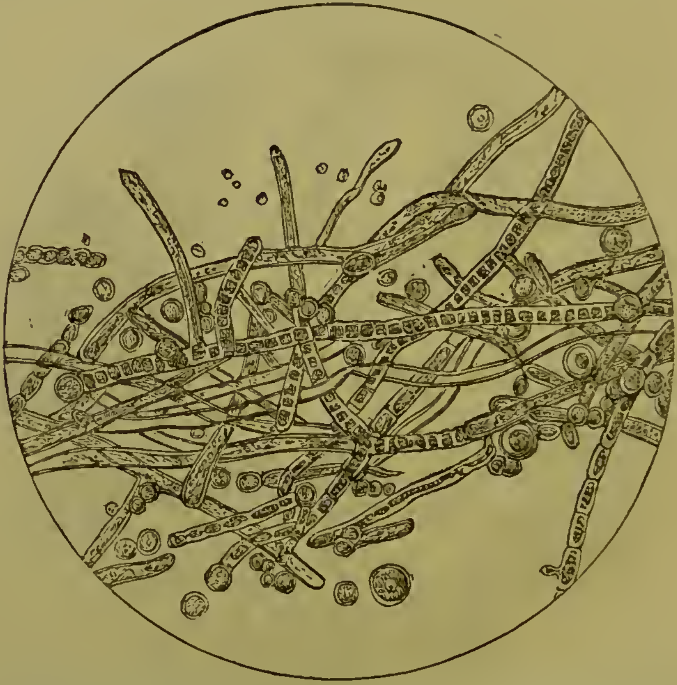
Fig. 103.



This engraving represents 'THE YEAST FUNGUS' in the first stage of its development, or that of sporules. As generally met with, and as used in the fermentation of bread, yeast consists of an immense number of similar sporules intermixed with bubbles of carbonic acid. Drawn with the Camera Lucida, and magnified 220 diameters.

Animated with the like desire of discovering the true development of this curious production, Dr. Pereira bestowed much time and attention on its examination. 'I have myself,' that gentleman writes, 'examined yeast at Messrs. Hanbury and Buxton's brewery at various stages of fermentation of both porter and ale, from a few hours to many days. In the more advanced stages of fermentation, I observed the globules of yeast were frequently in strings or rows, apparently forming moniliform, often branched plants. But as the cells or joints were very readily separable, I could not satisfy myself that the adhesion was otherwise than mechanical, such as we see between blood-discs when they arrange themselves in series like money-rolls, and such as we sometimes perceive even in inorganic amorphous precipitates. My experience agrees precisely with Schlossberger, who states that he "never could perceive a budding or bursting of the yeast-cells, accompanied by a discharge of their contents," nor could I ever produce this by compression. These curious brachial and other adjustments of the cells of yeast to each other appeared to me the work of chance.' It is, however, proper to add that the artificial rupture of the cells has been effected by Mitscherlich, who also confirms Turpin's observation of the budding of the yeast-cells.

Fig. 104.

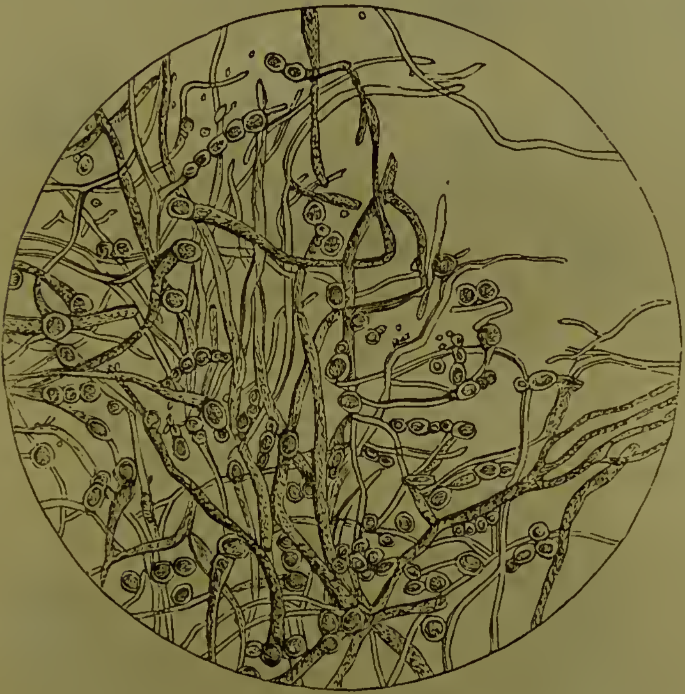


This engraving represents 'The Yeast-Plant' in the second stage of its growth, or that of thallus; the jointed threads are intermixed with the two kinds of reproductive bodies developed on the vertical filaments of the thallus. Drawn with the Camera Lucida, and magnified 220 diameters.

Robin, after describing the development of the sporules by budding, remarks: 'We know only this mode of propagation of this vegetable; but its fructification in the air has not been seen, nor can it be seen, because it perishes from the part at which it comes in contact with the atmosphere; so that we cannot yet say whether it ought to be classed amongst the fungi which fructify only in the air, or even amongst the algæ, from which it is separated by very many particulars, and which fructify under water.'

Impelled with a similar desire, we have applied ourselves diligently to this investigation, and, more fortunate than our predecessors, we have succeeded in tracing the yeast-plant through all the stages of its growth up to its perfect state.

Fig. 105.



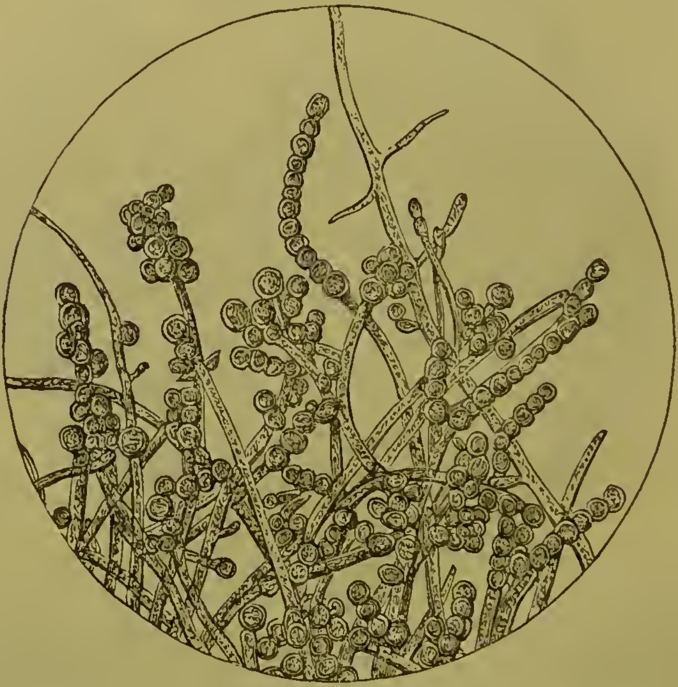
This engraving represents a peculiar state or condition of 'THE YEAST FUNGUS;' the filaments consist chiefly of thallus, but in the course of many of them, single vesicles, of a somewhat oval form, have appeared; the cavities of these are in general but imperfectly filled with granular matter, and the filament on one side of each vesicle is almost constantly enlarged and void of contents. The vesicles appear to be formed, as in many *algæ*, by the union of the contents of two or more cells, and the subsequent dilatation of the receiving cells. Drawn with the Camera Lucida, and magnified 220 diameters.

The development of the yeast-plant may be divided into three very distinct and natural stages.

First stage, or that of sporules.—In this, the ordinary state in which the yeast-plant is met with, it consists entirely of sporules. These are for the most part separate, but sometimes feebly united in twos, threes, and even in greater numbers; they vary in size and form, some are several times smaller than others, and nearly all contain one or two nuclei, which are the germs of future sporules (fig. 103).

Second stage, or that of thallus.—After the lapse of some days, and under favourable circumstances, the sporules become much elongated; a division or partition appears in each, and it now consists of two distinct cells. The extension still continuing, other septa appear, until at length jointed threads, at first simple and undivided, afterwards jointed, are formed, and the plant now exists in the form of root-like threads or *thallus* (figs. 104, 105 and 106).

Fig. 106.



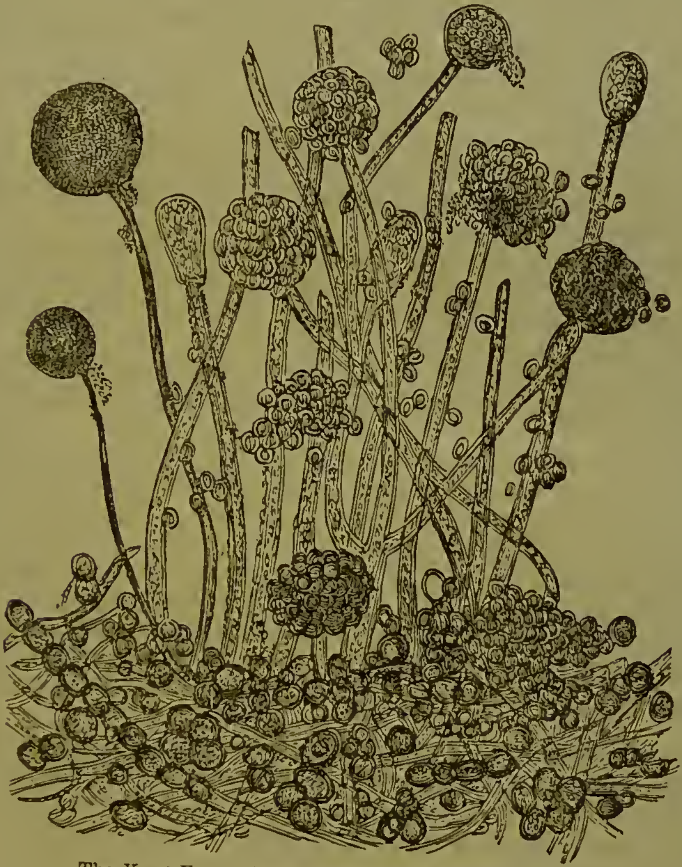
The yeast-plant in the state of thallus constitutes the *Mycoderma cerevisiæ* of Demazières.

Third stage, or that of aërial fructification.—After the lapse of a further time, vertical threads spring up from the thallus; these, when the plant has reached its complete development, become branched, each branch bearing at its extremity a row of rounded and beaded corpuscles.

These corpuscles are about the size of the original yeast sporules, but differ from those bodies in their darker colour and firmer texture. Occasionally in the rows of beaded corpuscles one cell several times larger than the rest is seen.

But from observations made subsequently on the development of the sugar fungus in saccharine urine, it appears that the beaded threads do not form the last condition or stage in the development of the plant, but that true aërial tufts or heads of sporules are formed.

Fig. 107.



The *Yeast Fungus* in its perfect state of development.

These heads were figured and described in a paper by ourselves, published in the 36th volume of 'Medico-Chirurgical Transactions,' p. 26. 'The state and appearance of the heads vary with the development. At first they present a smooth outline, from being covered by a delicate membrane; this afterwards bursting and becoming retracted, a rounded mass of circular sporules of a brownish colour is disclosed to view. The sporules falling off, leave the dilated extremities of the threads or filaments exposed.' (Fig. 107).

A fungus, somewhat closely resembling the yeast fungus in its perfect form, has been observed by Bennett in the expectoration of an individual attacked with pneumothorax.

Such, then, is a very brief description of the development of the yeast-plant in its several stages.

From a consideration of the structure of the granules of the yeast-plant, their evident fungoidal character, their rapid growth, &c., it occurred to us that the reason why the true or aërial reproduction had never been discovered was to be found in the fact that, yeast being used always in the state of sporules, sufficient time was not allowed it, under ordinary circumstances, to attain its full development, for which purpose probably many days would be required.

Acting on this impression, we placed in an eight-ounce bottle a tablespoonful of malt, poured over this about 4 ounces of warm water, and partially closing the mouth with a perforated cork, set it aside for a fortnight.

At the end of that time we were rejoiced to find that our expectations were fully realised, and that we had indeed discovered that which so many other observers had failed to detect. This discovery was made in August, 1850.

The aërial reproduction of this plant clearly shows that the German algologist, Kützing, is in error in regarding it as a confervoid production.

Modus operandi of yeast.—The presence of yeast in a substance containing sugar or starch which is convertible into sugar, and nitrogenised matter, induces certain chemical changes, comprehended under the term vinous or alcoholic fermentation.

These changes in the making of bread consist in the conversion of the sugar of the flour into *alcohol* and *carbonic acid gas*; the latter, in its efforts to escape from the dough with which it is mixed, distends it, forming vesicular spaces in its interior, and so causing it to become porous and light. Much of the alcohol is dissipated in the process of baking.

A small quantity of the starch is converted, by the agency of the yeast, into *sugar*, which, in its turn, is changed into alcohol and carbonic acid. If we examine attentively with the microscope the starch corpuscles contained in fermented and baked bread, we observe that they are for the most part still entire, although altered somewhat in form.

During the baking, part of the starch is undoubtedly converted into dextrin.

Some physicians are of opinion that the presence of yeast imparts injurious properties to leavened bread. This point is one of great practical importance; but so far as we are aware, no complete or conclusive observations have yet been made on the subject.

It has been computed that the annual loss of alcohol in bread-making amounts to about 300,000 gallons, which, at 19*s.* per gallon, would amount to 285,000*l.* The efforts hitherto made in large bakeries to save the alcohol have failed; 20,000*l.* were spent in the fruitless endeavour to collect and condense the alcohol in the military bakery at Chelsea.

For the production of wheaten bread of good quality it is of course necessary that the flour from which it is prepared should be sound and sweet. If the grain be much exposed to damp, or the flour made from it, if the grain from that cause have sprouted, the albuminous compounds of the flour will undergo decomposition, causing them, as already explained, to act as a ferment, and occasioning too great a conversion of the starch into dextrin, sugar, and other compounds, amongst which may be named acetic and lactic acids. Bread made with flour of this description is soddened, heavy, and of a dark colour.

Flours, therefore, which contain a large quantity of nitrogenous matter, as for example those made of whole meal flour, are more apt to undergo in bread-making an excessive degree of fermentation, than are the flours prepared from the more central and starchy portion of the grain.

The employment of alum.—In order to prevent the excessive action of the diastase, and also in some cases to modify and to arrest the action of the nitrogenous constituents of the flour when so changed in their nature as to act as ferments, the addition of mineral substances, and especially of alum, has long been resorted to, and it is affirmed that alum renders possible the use of many damaged flours which otherwise would either have to be wasted or used for other inferior purposes.

'The addition of alum to the dough,' writes Dr. Odling, in the 'Journal of the Society of Arts,' 1858, 'causes the loaves to be white, dry, elastic, crumbly, and unobjectionable both as to taste and appearance. I have found that flour which is of itself so glucogenic as to yield bread undistinguishable from that made with infusion of malt, could, by the addition of alum, be made to furnish a white, dry, eatable loaf.'

Alum is also credited with the further properties of preventing bread from turning sour and becoming mouldy. These statements must be received, we believe, with some limitation. Certain it is that it is a very common thing to meet with sour and mouldy bread containing alum. In so far as the alum restrains the production of excessive and undue fermentation, it may certainly have some effect in preventing the formation of acetic and especially lactic acid.

The opinion has long been entertained that alum possessed the power of causing bread to retain more water than it would otherwise do. It seems to be questionable whether this is really the case or not. Dr. Odling estimated the amount of water contained in the crumb on the day of baking of 18 loaves which contained alum, and 7 loaves free from alum, and found that in the former the average amount of water was 43·68, and in the latter 42·78 per cent. These experiments of Dr. Odling do not quite settle the point, as it is possible that the alum may cause the bread to retain its water for a longer time than if that substance were not present. It would be easy to determine this point by further experiments.

With reference to the use of alum, Dr. Dauglish has written:— 'Its effect on the system is that of a topical astringent on the surface of the alimentary canal, producing constipation and deranging the process of absorption. But its action in neutralising the efficacy of the digestive solvents is by far the most important and unquestionable. The very purpose for which it is used by the baker is the prevention of those early stages of solution which spoil the colour and lightness of the bread whilst it is being prepared, and which it does most effectually; but it does more than needed, for whilst it prevents solution at a time that is not desirable, it also continues its effects when taken into the stomach, and the consequence is that a large portion of the gluten and other valuable constituents of the flour are never properly dissolved, but pass through the alimentary canal without affording any nourishment whatever.'

The use of lime water was strongly recommended many years since by Liebig as a substitute for alum, it likewise preventing the transformation of the starch into dextrin, sugar, and lactic acid; and it has been employed in many cases for this purpose. It has the advantage of not interfering so much with the yeast fermentation, while no doubt its effects on the digestive organs would be less objectionable; but in this way it must be remembered that a certain amount of carbonate of lime is introduced into the bread. It is said that bread made with lime water has an agreeable taste, and that it is free from the sourness to which nearly all bread made in the ordinary way is more or less subject.

Sulphate of copper.—Another substance which has been employed for the same purpose, and which exerts a very powerful effect, is *sulphate of copper*. It is stated to have been much used in Belgium. 'An ounce of the salt being dissolved in about a quart of water, and a wineglassful of this solution mixed with the water necessary for 50 quartern or four-pound loaves. This quantity is extremely small; nevertheless, the use of so poisonous a substance as sulphate of copper cannot be too strongly condemned. Bread containing copper would be sure to act injuriously in the long run.'—*Watts's Dictionary*.

280 lbs. of flour, or one sack, should give from 90 to 105 4-lb. loaves. 6½ lbs. of dough yield about 6 lbs. of bread.

After being taken from the oven, bread begins to lose weight; according to Parkes, a 4-lb. loaf loses in 24 hours 1¼ oz.; in 48 hours, 5 ozs.; in 60, 7 ozs.; and in 70 hours nearly 9 ozs.

Loaves are generally weighed when hot, and this is considered to be their proper weight.

UNLEAVENED OR UNFERMENTED BREAD.

There are two kinds of unfermented bread; in the one, substances are used in imitation of yeast, from which a gas, always carbonic, is disengaged, distending the dough, and rendering it vesicular and light; in the other, flour, water, with perhaps the addition of salt, only are employed.

The substances used in the preparation of the first description of unfermented bread are *sesquicarbonate of ammonia, carbonate of soda* and *hydrochloric acid,* or *carbonate of soda* and *tartaric acid.*

Of these, by far the best is carbonate of ammonia; this is a volatile salt, and its great advantage is, that it is entirely or almost entirely dissipated by the heat employed in the preparation of the bread; and thus the necessary effect is produced without risk of injurious results ensuing.

In the employment of carbonate of soda and hydrochloric or muriatic acid, the case is, however, different; here we have the formation of chloride of sodium, or common salt, with disengagement of carbonic acid.

In those instances where a mixture of carbonate of soda and tartaric acid is used, tartrate of soda is formed, also with liberation of carbonic acid.

The preparations known as *Baking, Egg,* and *Custard powders* are combinations of carbonate of soda and tartaric acid, mixed with wheat flour, or other kind of starch, and the egg powders are often coloured with *turmeric,* and formerly also frequently with *chromate of lead.*

Of these preparations the most objectionable would appear to be that made with carbonate of soda and tartaric acid, since the resulting tartrate of soda possesses aperient properties. For our own part, we see much less objection to the employment, in the generality of cases, of a substance like yeast, which contains but little saline matter, and the vitality of which is for the most part destroyed by the heat of the oven, than in the use of acids and alkalies, for egg and baking powders.

Samples of 'baking powders' examined by us we found composed of tartaric acid and carbonate of soda, together frequently with ground rice or wheat flour.

It should be known that hydrochloric acid is frequently contaminated to a serious extent with *arsenic,* and hence its use may in some cases prove injurious.

It will be seen from the following published receipts for the preparation of unfermented bread, that the quantity of saline matter thus introduced into the system is by no means inconsiderable :—

To make White or Flour Bread.

Flour, dressed or household . .	3 lbs. avoirdupois.
Bicarbonate of soda, in powder .	9 drachms, apothecarics' weight.
Hydrochloric (muriatic) acid .	11¼ fluid drachms.
Water	about 25 fluid ounces.

Observe the large quantity of soda and acid recommended to be employed in the manufacture of a 3-lb. loaf.

Dr. Pereira gave the following receipt for the manufacture of unfermented bread; the proportions of soda and acid in this are much less:—

Receipt for Unfermented Bread.

Flour	1 lb.
Bicarbonate of soda	40 grains.
Cold water	½ pint.
Muriatic acid	50 drops.

Receipt for an Egg or Baking Powder.

Carbonate of soda	56 lbs.
Tartaric acid	28 lbs.
Potato flour	1 cwt.
Turmeric powder	¾ lb.

It will be observed that the quantity of tartaric acid in this receipt is too small to neutralise the soda. It is better adapted for pudding than bread.

The second description of unfermented bread is heavy and compact, and is met with chiefly in the form of biscuits.

While bread, therefore, made with yeast powders, may prove of service in some cases of dyspepsia, in others it is calculated to do harm.

AËRATED BREAD.

In the processes for the preparation of unfermented bread hitherto described, certain substances are introduced bodily into the dough, from which, when they come into contact, the carbonic acid is liberated, chloride of sodium or tartrate of soda being formed. Sometimes, as already pointed out, sesquicarbonate of ammonia is employed, and in this case the whole, or nearly the whole, of that salt is dissipated in the process of baking. We have shown that thus a considerable amount of mineral matter is introduced into the bread, and, in order to obviate this objection, it occurred to the late Dr. Dauglish first to liberate the carbonic acid, and then introduce it into the flour by means of water highly charged with the gas. The carbonic acid is obtained from chalk by the action of dilute sulphuric acid, is collected in a gasholder, from which it is made to pass into a vessel containing water, which thus becomes charged with the acid. The water so charged is then mixed with the flour under pressure, the dough becoming vesicular immediately on the removal of the pressure.

The advantages of the process are its certainty, its extreme cleanliness, its great rapidity, the saving of labour and material by the non-conversion of the sugar and a portion of the starch into carbonic acid and alcohol, the avoidance of extreme fermentation and the consequent production of acetic and lactic acids, rendering the use of the highly-nutritious whole-meal flour practicable in bread-making, and, lastly, there are the sanitary advantages, night work being rendered unnecessary.

Notwithstanding these many advantages, and the light, white and porous nature of the loaf, and very agreeable flavour of the bread made by this process, it does not appear that its use is extending, or that the process is likely to supersede the old method of the preparation of bread by the aid of yeast. It is said that persons quickly become tired of the aërated bread.

THE ANALYSIS OF BREAD.

The analysis of bread is conducted exactly in the same manner and on the same principles as that of flour, the important points to be ascertained in the case of really genuine bread being the amounts of water, glucose, dextrin, starch, cellulose, gluten, and mineral matter, including chloride of sodium.

The methods for the determination of all these have already been fully described, and need not be here repeated.

Of course if the bread be adulterated a variety of other determinations will have to be made, and which we shall presently notice.

But a bread may be genuine and yet of either inferior quality or damaged and unsound. It may be of inferior quality from deficiency of nitrogen, from changes in the nitrogenous constituents, and from undue fermentation. Some of these conditions would be revealed in the course of the analysis above sketched out, while the excessive fermentation would be in part ascertained by noting whether the bread exhibited an acid reaction, and, if so, estimating the amount of acid present, determining in some cases the amounts of the acetic and lactic acids separately. In this case the total acidity should first be determined; the volatile acid should then be removed by distillation from another portion of the bread, when the remaining fixed acid may be determined and regarded as lactic acid.

It may be damaged from the presence of one or other of the various organic productions, especially *fungi*, which have already been described under the head of the 'Diseases of the Cereal Grains,' and in this case we must have recourse to themicroscope for the discovery of the cause of the damage.

THE ADULTERATIONS OF BREAD.

The adulterations of bread of course correspond very closely with those of the flour from which it is prepared, and they may be all classified under the heads of *organic* and *mineral* adulterations.

We have already described what these adulterations are, for the most part, and we need here therefore only refer to those which have either not been mentioned before, or which have been as yet insufficiently treated. Amongst the former are those with *water*, *mashed* *potatoes*, and *boiled rice*, while amongst the latter are *alum* and *sulphate of copper.*

With water.—Of course, since bread is sold by weight, it is important to the baker that it should contain as much water as possible. We have seen that new bread contains on an average as much as 42·8 per cent. of water, of which about 10 parts are natural to the flour. Now bread is made to retain an increased quantity of water in several ways.

One method is, after having incorporated as much water in the dough as possible, to put it into a hot oven. This causes the crust to form speedily, which prevents the escape of water.

The same object is attained by throwing sacks over the loaves immediately after their removal from the oven. This prevents the dissipation of some of the water which passes off so quickly from the hot loaves.

A third method is by the employment of *rice.* This, when cooked, swells up greatly and absorbs much water.

Potatoes, when used in any quantity, have probably the same effect.

It was for a long time believed that alum also caused the bread in which it is contained to hold more water, but this would appear from Dr. Odling's experiments not to be the case, at all events, in newly-baked loaves.

With mashed potatoes.—It is also notorious that bakers frequently add a proportion of potatoes to bread. These, when mashed, are mixed with the yeast, which is said to feed upon the potatoes, and for which purpose only it is alleged the potatoes are used, and not for adulteration. When the quantity of potatoes employed is but small, this may be so; but there is no doubt that they are sometimes added in considerable quantities to bread, especially when they are cheap.

Now the potato in its raw state contains about 75 per cent. of water, and as commonly served up to table even a little more, so that this adulteration really causes the bread to contain more water, and so robs it of a portion of its nutritive properties. Again, the potato contains only half as much nitrogen as wheat flour.

With boiled rice.—This also is not unfrequently added to bread, and its presence likewise impairs its nutritive properties in two ways: first, rice contains far less nitrogen than does wheat (about 7 per cent. only); and, second, it causes the bread to hold more water than it would do if made of wheat flour alone, and thus the quality of the bread as a life-sustaining food is still further reduced. Boiled rice contains about 77 per cent. of water.

With sulphate of alumina and potash or alum.—We have already treated to some extent of the adulteration of bread with alum, but we have by no means as yet exhausted the subject.

It is notorious that many bakers add either alum to their bread or a mixture of alum and salt known in the trade by the terms 'hards' and 'stuff;' and thus in many cases the flour receives two additions of alum, the baker being often unaware that he has been already anticipated by the miller.

The use of *alum* in bread is *particularly injurious.* It is true that it causes the bread to be whiter than it would be otherwise, indeed, whiter than it was ever intended to be by nature; but it imparts to bread several other properties: thus it hardens the nutritious constituent of the bread, the gluten, and so, on the authority of that great chemist Liebig, renders the bread more indigestible; it enables the baker to adulterate his bread with greater quantities of rice and potatoes than he could otherwise employ; and, lastly, by the use of alum he is able to pass off an inferior, and even a damaged flour, for one of superior quality. Is it worth while to injure the properties of the bread by using alum for the sake of obtaining an unnaturally white loaf?

The public, then, in judging of the quality of bread by its colour —by its whiteness—commits a most serious mistake: there is little or no connection between colour and quality; in fact, very generally, the whitest breads are the most adulterated. The public, therefore, should lose no time in correcting its judgment on this point.

The outer part of the grain of wheat has been proved by analysis to be much richer in nourishing principles, in gluten and in oily matter especially, than the central and more floury parts of the grain. Now, in preparing the finer descriptions of flour, the utmost pains are taken to separate this highly nutritious exterior portion of the grain, and thus, although the flour so obtained is very fine and white—very suitable for making a white loaf, that fallacious test of quality—it is yet not nearly so nutritious as whole-meal flour, or even the less finely dressed qualities of wheat flour. The consumer, now better instructed, is in a position to judge of how much he sacrifices for the mere sake of an arbitrary and fallacious standard of quality, namely whiteness. The difference in nourishing properties between whole-meal flour and very finely dressed flour amounts in many cases to fully one-third.

Further, alum is very apt to disorder the stomach, and to occasion acidity and dyspepsia.

The manner in which it does so has not been clearly ascertained. The powerful effects of alum as an astringent, when administered as a medicine, are well known; but when added to flour or bread, it becomes decomposed, sulphate of potash, an aperient salt, being formed.

Liebig considers that part of the beneficial action of wheat flour on the system is due to the soluble phosphates which it contains in such large quantities, and he states that when alum is added to bread these are decomposed, the phosphoric acid of the phosphates uniting with the alumina of the alum, and that thus an insoluble phosphate of alumina is formed, and the beneficial action of the phosphates consequently lost to the system.

So satisfied is Liebig that this is the case, that he has recommended the employment of small quantities of lime water for the purpose of whitening bread made from musty or damaged flour; and it was stated at a meeting of the British Association at Glasgow that lime water is now used by many Scotch bakers.

The following is Liebig's own statement of his views:—

'Many salts render the gluten again insoluble, apparently by forming with it a chemical combination.

'The bakers of Belgium discovered, about twenty years ago, how to bake from damaged flour—by adding sulphate of copper (a poison) to the dough—a bread in appearance and external properties as fine as from the best wheat flour. This mode of improving its physical properties of course deteriorates its chemical properties. Alum has the same effect as sulphate of copper: when added to the dough it renders the bread very light, elastic, firm, and dry; and the London bakers, in consequence of the demand for white bread, such as the English and American flours, usually so good, yield, appear to have been compelled to add alum to all flour in the baking. I saw in an alum manufactory in Scotland, little mounds of finely-ground alum, which was destined for the use of the London bakers.

'Since phosphoric acid forms with alumina a compound hardly decomposable by alkalies or acids, this may perhaps explain the indigestibility of the London baker's bread, which strikes all foreigners. A small quantity of lime water added to the musty or damaged flour, has the same effect as the alum or sulphate of copper, without being followed by the same disadvantages.'—*Letters on Chemistry.*

Enough has now been adduced to show that it is a very dangerous thing to tamper with articles of daily food and of large consumption, like flour and bread, by the addition of chemical substances of any kind.

It is curious to notice the arguments to which the defenders of adulteration are driven in order to find excuses for certain practices. We were some years since much astonished at one of these arguments.

A learned chemical professor, at a late meeting of the British Association in Glasgow, defended the use of alum in bread on the following ground:—

He stated that Thames water was so alkaline, it turned the flour *yellow*, and hence the use of an acid became necessary.

Home-made bread is certainly not so white as baker's bread, the difference being explained by the absence of the alum; but it is certainly not the case that Thames water has the remarkable effect of turning the flour yellow.

But the real and actual facts, as regards Thames water and its effects on the colour of the bread, are these:—

The alkalinity of Thames water is so trifling that it is scarcely perceptible to the most delicate test paper; again, during the fermentation of the bread a large quantity of acid is generated, infinitely more than would be sufficient to neutralise the alleged alkalinity of Thames water, and to counteract any tendency which it is said to possess to turn flour yellow.

Again, contrast the professor's *argument* with the *practice* recommended by Baron Liebig. The one says Thames water is so alkaline it turns flour yellow, and the other advises the use of an alkali to whiten it.

But we will suppose that the professor's views are not altogether destitute of foundation, yet they would constitute but a poor reason for the employment of alum. That substance is used in bread-making nearly all over the United Kingdom, and yet the use of Thames water is confined to the metropolis and its vicinity. We repeat, then, it is curious to notice the character of the arguments which sometimes even scientific men will condescend to use in defence of adulteration.

Another argument by which the use of alum is defended is that the quantity employed is but small: upon this point the following evidence may be adduced:—

The author of the celebrated treatise 'Death in the Pot,' writes:—

'The smallest quantity of alum which can be employed with effect to produce a white, light, and porous bread from an inferior kind of flour, I have my own baker's authority to state, is from three to four ounces of alum to a sack of flour weighing 240 lbs.'

Dr. Markham gives eight ounces of alum as the quantity used to a sack of flour.

From enquiries which we have made amongst bakers we find that the quantity of alum usually employed is half a pound to the sack of flour weighing 240 lbs., and that the quantity used varies according to the age and condition of the flour; thus new flour requires much more alum than old; indeed, a white bread may be made from old flour without any addition of alum, while as much as three-quarters of a pound may be added to the sack of very new flour. New flour is that which comes into use about November and December: hence the bread made in these months usually contains a large proportion of alum. Old flour is that used in the two or three summer months preceding the harvest.

Four ounces give about 30 grains of alum to every 4 lbs. of flour, eight ounces 60 grains, and twelve ounces 90 grains. Mr. Mitchell, the author of a treatise on the 'Falsification of Food,' states that he detected in ten 4-lb. loaves of bread, 819½ grains of alum.

With respect to condition, a flour which is weak—that is, which does not bind readily in consequence of a deficiency of gluten—requires a much larger proportion of alum, and in this case from three-quarters to a pound of that salt may be added.

Salt has much the same effect as alum; that is, it makes the bread white and firm, and hence it is sometimes used in excess, to supply the place, to some extent, of alum. The average quantity of salt added by bakers to bread wherein alum is used is not less than about sixty ounces to the 240 lbs.; but the amount varies with the age of the flour.

With sulphate of copper.—This poisonous salt has been employed, as has been already noticed in this report, more than once for the same purposes as alum—namely, to harden the gluten, and to impart an unnatural whiteness to the flour.

With other adulterants.—Several other articles, in addition to those just enumerated, are stated to be employed in the adulteration of bread, and there is no doubt that they have been thus used. These are *bone ashes, bone dust, white clay* or *silicate of alumina*, the *carbonates of soda, magnesia*, and *lime*, and lastly, *mineral white, terra alba* or *hydrated sulphate of lime.* These several substances are chiefly introduced through the flour with which the bread is made.

Results of the Examinations of numerous samples of Bread for Alum.

Of twenty-eight samples of bread tested for alum some time back, that substance was found in every one of the samples.

Some time subsequently, a second series of samples of bread, twenty-five in number, were also tested for alum, and this salt was found in the whole of the samples.

Three of the bakers whose bread was examined, and found to contain alum, declared that they did not add that substance to their bread; and they placed in our hands samples of the flour of which the breads were made, when the alum was found in the flours.

From this it may be inferred that the alum had been introduced into the flours by the millers. This discovery led to the examination of other flours, in several of which alum was also detected.

These results are certainly far less favourable than those which would now be obtained by an examination of an equal number of samples, as of late many of the more respectable bakers have entirely abandoned the addition of alum to their bread.

On the weight of bread.—In the course of our investigations respecting the adulteration of bread, we did not fail to pay some attention to the subject of the *weight of bread*, a subject second in importance only to that of its adulteration. We procured a number of loaves of bread from different bakers, as delivered to houses, and weighed them. The results were, that thirty-one and a half loaves, obtained from thirteen different bakers, were deficient *eighty-six* ounces. Scarcely a single loaf reached its proper weight.

In order to check dishonesty in the weight of bread, the following simple plan is in operation in Edinburgh, and it is described by the gentleman who suggested it as having worked exceedingly well.

It is made imperative on the baker to stamp the weight upon all the loaves he sells. A provision to this effect is contained in the Police Act of Edinburgh.

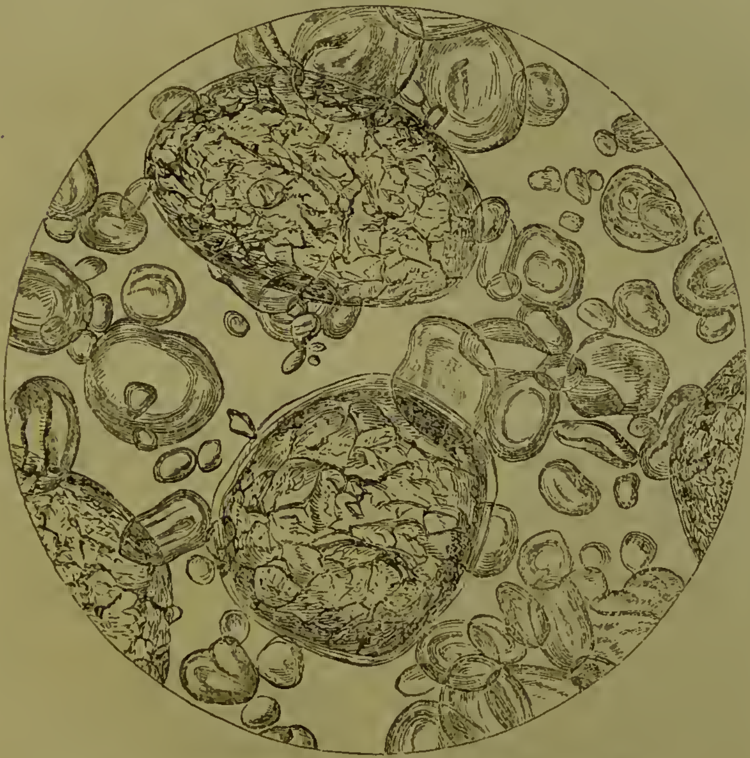
THE DETECTION OF THE ADULTERATIONS OF BREAD.

The various substances and articles employed in the adulteration of flour and bread, may be classified into the *organic* and *inorganic*; under the first head are included *bean, rice, rye, barley*, and *Indian corn flours, potato flour, potatoes*, and *bone dust*; under the second, *sulphate of alumina* and *potash*, or *alum, sulphate of copper, sulphate of lime*; other names for which are *plaster of Paris, gypsum, terra alba* or *mineral white, silicate of magnesia, white clay, carbonates of lime, magnesia*, and *soda, bone ashes* or *phosphate of lime.*

The Detection of the Organic Adulterations of Bread.

The only means by which the adulterations of bread with the different kinds of flour enumerated can be discovered, is by the microscope.

Fig. 108.



Wheat Bread, adulterated with *potato*. Magnified 420 diameters.

The discovery is very much more easily effected in flour than in bread, because the heat to which bread is subjected in baking alters greatly the original form of the starch granules, and so renders their identification most difficult, and in some cases impossible.

The characters of the starches of the several flours used in the adulteration of bread have already been described.

In those cases in which it is impossible to recognise the starch granules by means of the microscope, in consequence of the alterations which they have undergone, search should be made for portions of the husk of the several grains, as these are much less affected by the heat and moisture than the starch granules themselves.

It is often extremely difficult to detect the presence of even boiled and mashed potatoes in bread, and this in cases in which it is certain that they have been used, as when only a small quantity of potatoes has been added for the yeast to feed upon. This difficulty, we believe, arises from the fact that the potato cells and starch granules become entirely broken up and destroyed, as a consequence of the fermentation which takes place during the preparation of the patent yeast. When, however, potatoes are employed in larger quantity and are added direct to the flour, the detection of the potato cells is easily effected by the microscope.

The method for the discovery of *bone dust*, the last of the organic adulterations, will be found described under the head of 'Flour.'

The Detection of the Inorganic Adulterations of Bread.

The methods for the detection and estimation of nearly the whole of the inorganic adulterations of bread will be found described in the article on 'Flour,' and it will only therefore be necessary in this place to give the more important processes for the detection and estimation of alum and sulphate of copper.

On the detection of alum in bread.—Much has been written, and much discussion has taken place, in reference to the methods to be pursued for the detection and estimation of alum. The perusal of all that has been written on this subject would lead an ordinary observer to form the opinion that the detection and estimation of alum in bread constituted one of the most difficult operations in chemistry. This is really not so, however, and there are several processes whereby this salt may be estimated with ease and undoubted accuracy. We shall notice only those methods which are the most practical, and at the same time accurate.

Alum is crystallised sulphate of alumina and potash. In general, in analysing flour or bread for this substance, it is not necessary to do more than estimate the alumina, this being a substance which is not assimilated by plants, and which, consequently, does not occur in the ash of the cereals. It is safest, however, when we desire to exclude every possibility of a mistake, to estimate the amount of sulphuric acid as well. The quantity of sulphuric acid naturally occurring in the ash of the grain is of course to be deducted. The following is one of the best and simplest processes which can be adopted:—

Incinerate in a platinum basin 75 grammes of the flour, or 100 grammes of the crumb of the bread. The incineration, although slow, yields a perfectly white ash, free from all carbonaceous matter; but if time is an object, the bread, after being charred, may be reduced to powder and incinerated in a muffle. The ash is boiled in the platinum basin with some strong hydrochloric acid and evaporated to dryness on the water-bath, in order to render insoluble any silica which might have been in solution. The dried mass is moistened and heated with a few drops of strong hydrochloric acid; 50 cc. of water are then added, and the solution, which contains the alumina as chloride of aluminum, is filtered. The filtrate is rendered strongly alkaline by a solution of *pure potash.* The potash precipitates the phosphates of lime and magnesia, while the alumina is kept in solution. The alkaline solution is boiled, and after filtration is slightly acidulated with pure hydrochloric acid, and then ammonia is added until the reaction of the liquid is decidedly alkaline. If any precipitate be thrown down, this consists of alumina, more or less combined with phosphoric acid, phosphate of alumina being perfectly analogous in many of its properties with pure alumina. The precipitate is separated by filtration, washed, incinerated, and weighed. It is then decomposed by fusion with carbonate of soda, the mass is dissolved in nitric acid, and in the solution the phosphoric acid is estimated as described under the head of 'Tea.' The amount of phosphoric acid is to be subtracted from the weight of the phosphoric acid and alumina obtained, when the exact amount of alumina will be ascertained.

To avoid the troublesome estimation of the phosphoric acid, we are in the habit of adding a few drops of phosphate of soda to the solution before precipitating with ammonia. Pure phosphate of alumina is then thrown down, which may easily be calculated for alum. 100 parts of alumina correspond to 711·8 parts of crystallised alum, and 100 parts of phosphate of alumina to 299·2 parts of alum.

Another method, which is based on thoroughly scientific principles, but which is rather complicated, has been proposed by Dr. Dupré, 'Chem. News,' Vol. xxix., No. 757:—'One hundred grammes of bread (crumb only) are carefully incinerated in a platinum dish. The ash is fused in the dish, with about three times its weight of pure carbonate of sodium, or of a mixture of the carbonates of potassium and sodium in equal proportion. The incineration and fusion are best performed in a muffle. The fused mass is dissolved in hydrochloric acid, and the solution is evaporated to dryness. The residue is redissolved in acid, and the silica filtered off as usual. To the filtrate ammonia is added, until a slight permanent precipitation is produced, which is then redissolved by about six drops of strong hydrochloric acid. A slight excess of acetate of ammonium is now added, and the mixture is set aside over night. Next morning the precipitate formed is filtered off, washed, and redissolved in hydrochloric acid. The solution is boiled for a few minutes with a small quantity of bisulphite of sodium, and an excess of caustic soda is added, and the boiling continued for a few minutes longer. The precipitate, chiefly magnetic oxide of iron, is filtered off, the filtrate is rendered feebly acid by hydrochloric acid, and acetate of ammonia added in slight excess. After standing over-night the precipitate, now consisting of pure phosphate of aluminum, is collected on a filter, washed, dried, ignited, and weighed. By multiplying its weight in grammes by 542, the number of grains of alum corresponding to the amount of alumina present in 2 lbs. of the bread is obtained.'

In both these methods it is of the highest importance to employ pure reagents. The hydrochloric acid and the ammonia never contain any alumina, but the caustic potash or soda is exceedingly liable to be largely contaminated with it. Care therefore must be taken to use only pure potash or soda; the solution must be freshly prepared, and not allowed to stand for any length of time in a glass flask or bottle, from which it would be sure to dissolve alumina. It is advisable to *measure* the quantities of *all* reagents used in the course of the examination, and to make a blank experiment with the same quantities, determining if necessary the amount of alumina found in them. This, of course, is to be deducted from the alumina obtained from the flour or bread. But it is best to take the most scrupulous care to procure *pure* chemicals.

Any part of the process which can be conducted in platinum vessels ought to be executed therein; glass and porcelain vessels should be avoided. The alkaline solution must *never* be boiled in glass or porcelain.

It has been alleged that by the evaporation of the hydrochloric acid solution chloride of aluminum was sure to be volatilised. Only the grossest ignorance of chemistry can lead to such an assertion. Chloride of aluminium, $Al_2 Cl_6$, is volatile, it is true, but only when anhydrous. Evaporated in contact with water, it forms hydrochloric acid and alumina, or basic chloride of aluminum. A loss of aluminum by volatilisation from a watery or acid solution is absolutely impossible.

Other processes have been proposed, but we consider it superfluous to enter into a description of them. One or other of the two methods described is sure to give correct results. With care and practice the detection of alum in bread is not difficult, and mistakes, which recently have not unfrequently occurred, are mainly due to want of knowledge and care.

We refer to the following process in order that it may be avoided: 'Soak the flour or bread in water, filter the solution and treat with ammonia; the precipitate which ensues is alumina.' Nothing can be more absurd than this. As we have seen, alum is, in bread, not contained as such, but as insoluble phosphate of alumina. How, then, can it be extracted by water? A precipitate will always be obtained, but this consists of nitrogenous matter and of earthy phosphates.

Another fallacious test is the *logwood* test. We have frequently employed this test in cases in which alum has been present without obtaining the slightest violet coloration.

The sulphuric acid may, as already mentioned, be estimated to corroborate the results obtained by the estimation of the alumina.

50 grammes of bread are incinerated, the ash is treated with pure hydrochloric acid, and in the solution the sulphuric acid is precipitated by means of chloride of barium. The sulphate of barium is filtered off, washed, weighed, incinerated, and calculated for sulphuric acid.

It is said that the salt used in bread-making may contain a little alumina, but we have not found this to be the case usually, and if present at all the quantity is generally extremely minute.

On the detection of sulphate of copper.—For the detection of copper in bread the processes described under the heads of 'Bottled Fruits and Vegetables' and 'Pickles' should be followed.

Ferrocyanide of potassium is a very delicate test for copper in bread. If the bread be moistened with a solution of that salt, it will, it is said, assume a pink tinge, more or less deep according to the quantity present. It is stated that one part of copper may thus be detected in 9,000 parts of bread.

For the detection of copper in the ash, from 200 to 300 grammes of bread should be incinerated.

CHAPTER XIII.

OATMEAL AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Admixture with any flour or farina other than that of oats, with any foreign vegetable or mineral matter, or an undue proportion of the husk of the oat or of other grain.

OATMEAL, as its name implies, consists of the farina or meal of the oat, *Avena sativa.*

The composition and properties of this cereal grain have already been described under the article 'Flour,' as also its minute structure, which will be found represented in figs. 79 and 80.

Analyses of oats will be found at pp. 298 and 299.

From the analyses given it appears that oatmeal is a highly nutritive article of diet, richer than even wheat flour in oily and nitrogenous matters.

There are several varieties or qualities of oatmeal: one of these is Robinson's Patent Groats: this consists of the finest parts of the flour of the oat, all husk and the outer and harder parts of the grain being removed; another variety is called 'round oatmeal;' it consists of the oats deprived of husk and ground into a very coarse powder. This description varies a good deal, the outer surface of the oats intended for the better sorts being rubbed off by attrition between stones.

In the preparation of fine oatmeal there is a good deal of refuse matter, amounting generally to about one fourth or fifth of the entire bulk of the oats; this is composed of a portion of husk, which contains much silex, and the outer part of the grain, containing a little starch and much oil and nitrogenous matter; this is usually mixed up with the commoner descriptions of oatmeal, especially that supplied to workhouses.

Lastly, the quality of oatmeal depends very greatly upon that of the oat from which the meal is prepared.

THE ADULTERATIONS OF OATMEAL.

It could hardly be supposed that sufficient inducement exists for the sophistication of an article like oatmeal; it appears, however, that this supposition is not correct.

Of *thirty* samples of oatmeal submitted to examination some time since, *sixteen*, or rather more than one-half, *were found to be adulterated* with large quantities of Barley Meal. But oatmeal frequently suffers deterioration in other ways besides by admixture with barley flour. One of these consists in adding to it the investing membranes, or *husk*, of the *oat*, *barley*, and *wheat*, technically termed 'rubble' and 'sharps,' and which are rejected in the preparation of the purer sorts of oatmeal, grits and groats, Scotch and pearl barley.

A very great difference exists between the prices of oats and barley, the latter costing usually only about one-half the former. The inducement, therefore, to adulterate oatmeal is very great.

The following information, furnished us some years since by a correspondent on whom we can rely, shows this article to be subject to systematic adulteration. He writes:—

'Since your able analyses have taken place it has struck me that I may be able to give you a little information as to an article of food which is adulterated to a most *awful* extent—viz., *oatmeal*. I will first mention oatmeal *as sent into workhouses*, *prisons*, and *charitable institutions*, which are generally taken at contract prices. I enclose one for the parish of —— for 1848, where I find the oatmeal was taken at 14*s*. per cwt. by ——; and by reference to my stock-book, I find the market price was 17*s*. 6*d*. per cwt.; thus the oatmeal was reduced 3*s*. 6*d*., and then left an excellent profit. Well, at that time I was trying for all the contracts in London, and could not succeed, my *prices* being generally about 4*s*. dearer than anyone's else; this was a *mystery* to me. By accident I found out oatmeal was adulterated with barley flour, which is bought at about 7*s*. per cwt; this being mixed with the oatmeal, of course reduced the *price*. I then, being as wise as my competitors, tried, and have served the above workhouse since.

'Now, the fault lies here. If the workhouses were to take the contracts at a percentage on market value, then they would get *good* oatmeal; but they always *cut down* the price, and thus get an adulterated article.

'You will see the prices are 14*s*., 15*s*. 6*d*., 16*s*., and 17*s*.; thus if a man wants to be *honest* with them, *they will not let him*. I have again and again wished to supply at a percentage on market value; the answer I get is, "*Well, we are very well satisfied, and have no complaints.*"'

We were ourselves at some pains to verify the statements made above, and for that purpose procured samples of oatmeal as supplied to some of our unions and charitable institutions; these, without exception, we found on examination to be largely adulterated with *barley meal*, as described.

Other adulterations of oatmeal are, according to Professor Calvert, with *rice* and *maize*. He stated, in his evidence, already referred to elsewhere:—'I have found oatmeal, generally speaking, in fact always, mixed with rice and maize. The effect is this—it makes less porridge; in other words, it is a direct loss to the ratepayers, because the cook in the workhouse must use a larger proportion of this adulterated oatmeal to make a certain quantity of porridge, than if it is pure oatmeal.'

The following evidence was furnished to the Committee on Adulteration, in 1855, by Mr. Mackenzie, of Glasgow, the editor of 'The Reformer's Gazette,' in regard to the adulteration of oatmeal:—

'Some few years ago, when great destitution prevailed in the West of Scotland, especially in the Highlands, a large sum of money, amounting to 50,000*l.* or 60,000*l.*, was devoted to furnishing provisions, including oatmeal, to the Highlanders. At that period information was given me that a very large quantity of that oatmeal was adulterated in the grossest manner: a letter was sent to me, which I thought it my duty to publish, and the contractor who furnished the meal referred to in that letter threatened me with an action of damages. The case was tried, and the contractor found guilty, and adjudged to imprisonment for three months, and to pay a fine of 300*l.* The oatmeal was mixed with bran and thirds, the common food for horses;' thirds being the refuse and shell of the wheat.

'To my amazement,' continues Mr. Mackenzie, 'the accused brought forward some of the principal millers in Glasgow to swear that it was quite a common practice (in fact, one of the "usages") of the trade.'

The adulteration of oatmeal is not merely important in a pecuniary, but is of some consequence in a sanitary point of view.

The properties of *oatmeal* are thus described in Pereira's 'Materia Medica:'—'Oatmeal is an important and valuable article of food. With the exception of maize or Indian corn, it is richer in oily and fatty matter than any of the other cultivated cereal grains, and its proportion of protein compounds exceeds that of the finest English wheaten flour. So that both with respect to its heat and fat making, and its flesh and blood making principles, it holds a high rank.'

In the same work we meet with the following account of *barley meal* as an article of diet:—'Barley is a valuable nutritive. Considered in relation to wheat, it offers several peculiarities. In the first place, it contains much less protein matter; in other words, less of the flesh and blood making principle; though Count Rumford considered barley meal in soup three or four times as nutritious as wheat flour. Secondly, its starch offers more resistance to the action of the gastric juice, in consequence of its more difficult solubility in water. Thirdly, its husk is slightly acrid, and therefore this should be removed from barley intended for dietetical purposes, as in Scotch and pearl barley. Fourthly, barley meal is more laxative than wheat meal.'

Contrasting the two, it appears that oatmeal possesses considerable dietetic advantages over barley meal.

It may be in the recollection of some of our readers that at the inquest held by the late Mr. Wakley on the bodies of some of the poor children who fell victims in the pest-house at Tooting, the fact transpired that the oatmeal, which formed so considerable a part of their food, was extensively adulterated with barley meal.

THE DETECTION OF THE ADULTERATIONS OF OATMEAL.

The principal adulterations of oatmeal, as already noticed, are those with the *refuse matter of oats, of barley,* and even *wheat,* termed 'rubble' and 'sharps,' and with *barley meal* and *rice* and *maize* flours; these adulterations may be detected without, in most cases, any considerable difficulty.

On the detection of 'rubble.'—An admixture of rubble may be suspected when the sample presents a branny appearance, in consequence of the presence of numerous particles of husk or bran, as well as of the outer yellow portion of the grain. In order, however, to ensure certainty it is necessary to resort to chemistry and the microscope. A portion of the article may be analysed quantitatively for silicic acid; the ash of about 10 grammes must be boiled with dilute hydrochloric acid, and evaporated to dryness; the residue is again taken up with hydrochloric acid. This will dissolve all but the silica, which must be washed, ignited, and weighed.

Of course the percentage of silica in rubble is very much higher than it is in the whole grain.

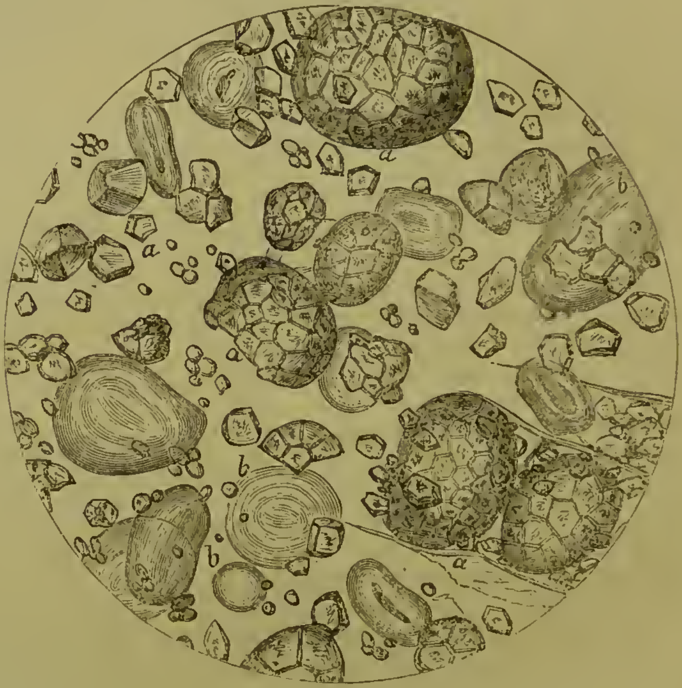
In those cases in which the *rubble of barley* meal has been used the starch granules of that cereal may be readily detected by means of the microscope, as also portions of the investing membranes, the structures of which, so different from those of oat, are described at p. 294, and figured at p. 291.

In like manner, the microscope furnishes the means of discovering the presence of *wheat rubble or sharps* in oatmeal. The starch granules of wheat and barley so nearly resemble each other, that when mixed together it is impossible to distinguish the one from the other; the investing membranes of the grain of wheat, described and figured at pp. 287 and 288, are, however, so different from those of barley, that they afford a certain means of discrimination.

On the detection of barley meal.—The microscope affords the only means by which this adulteration can be discovered. The starch granules of oat and barley have already been described and figures of them given; the differences are so great, that a momentary glance with the microscope is all that is necessary to enable the observer to distinguish genuine oatmeal from that adulterated with barley meal or wheat flour. The starch granules of the oat are small, angular, and frequently aggregated into compound bodies of a rounded form, while those of barley are much larger, round, and flat. But the main distinction is furnished by the differences in the structure of the investing membranes comprising the husk.

It is very possible, however, to mistake the starch granules of wheat for those of barley; but wheat flour is rarely used in the adulteration of oatmeal; this error may be avoided by a careful examination of the portions of testæ met with, the structure of which in wheat, barley, and oat is so very different, as will appear from an examination of the descriptions and figures given under the article 'Flour.'

Fig. 109.



OATMEAL adulterated with *barley meal*. Magnified 225 diameters.

On the detection of rice and maize.—These adulterations may be promptly discovered by means of the microscope. (See fig. 84, p. 308, and fig. 81, p. 302.)

CHAPTER XIV.

ARROWROOT AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any other starch or farina than that indicated by the name under which it is sold, or any added vegetable or mineral substance. Arrowroot should be distinguished rather by the name of the plant from which it is derived than by that of the locality in which it is grown. Mixtures of more than one kind of arrowroot to be sold as mixtures.

THE term 'arrowroot' was originally applied to the rhizome or root of *Maranta arundinacea*, in consequence of its supposed efficacy in counteracting the effects of wounds inflicted by poisoned arrows.

Of late years the signification of the term has been much extended, and it is now employed to designate almost every fecula which bears any resemblance to true or Maranta arrowroot, no matter how dissimilar the plants may be from which it is obtained.

Attending this enlarged use of the word arrowroot are certain disadvantages. Many persons consider that all arrowroots constitute one and the same article, varying only in quality, and according to the place from which they are procured; while but few persons are aware that there are several distinct kinds of arrowroot, the produce of different plants, great uncertainty and confusion being thus created.

To increase this confusion, the word 'genuine' is often prefixed to the term 'arrowroot,' and as there are several kinds of arrowroot, so must there be several genuine arrowroots. These vary in value from a few pence to two or three shillings the pound—from, in fact, the value of genuine Maranta arrowroot to that of genuine potato arrowroot. With these particulars the public at large are but ill acquainted.

The difficulty and confusion are still further enhanced by applying to the arrowroot, as is generally done, the name of the place from which it is obtained; thus we have genuine West Indian, Jamaica, Demerara, Bermuda, St. Vincent, East Indian, Brazilian, African, Guinea, Sierra Leone, Portland, British, and a variety of other arrowroots. Some persons suppose that each of these names represents a different kind of arrowroot; others imagine that they all indicate one and the same production; while the fact is, that in some cases, as in that of East India arrowroot, one name may be indiscriminately applied to two distinct kinds of arrowroot, and in others, six or eight names all signify but a single kind or species, as is the case with West India arrowroot. This great variety of names is objectionable, not merely because it tends to confuse the public, but because it offers to the fraudulent great facilities for adulteration and imposition, of which, as we shall see hereafter, they have not failed to avail themselves.

The remedy for this state of things is simple; each really distinct arrowroot, that is, every arrowroot which is the product of a distinct plant, should be designated by the name of the species from which it is derived, as Maranta, Curcuma, Tacca, Manihot, Arum, Potato Arrowroot, &c.

The employment of these terms should not be optional, but *compulsory*, for the better protection of the public against fraud in this article of food. The propriety of this suggestion will become still more evident as we proceed.

We shall now describe each kind of arrowroot separately, observing of them all, that when pure they are non-nitrogenised substances, and therefore adapted to the formation of the fat of the body, and to the maintenance of respiration and temperature.

MARANTA ARROWROOT.

Maranta arrowroot is obtained from the rhizomes of *Maranta arundinacea*, one of the family of the *Marantaceæ*.

A rhizome is an underground jointed stem placed horizontally in the earth, giving off from its upper surface branches, and from the lower radicles or roots; the starch or fecula is contained in the joints of the rhizome, being deposited in innumerable minute cells.

The following account of its preparation is given by Dr. Pereira in his 'Materia Medica':—

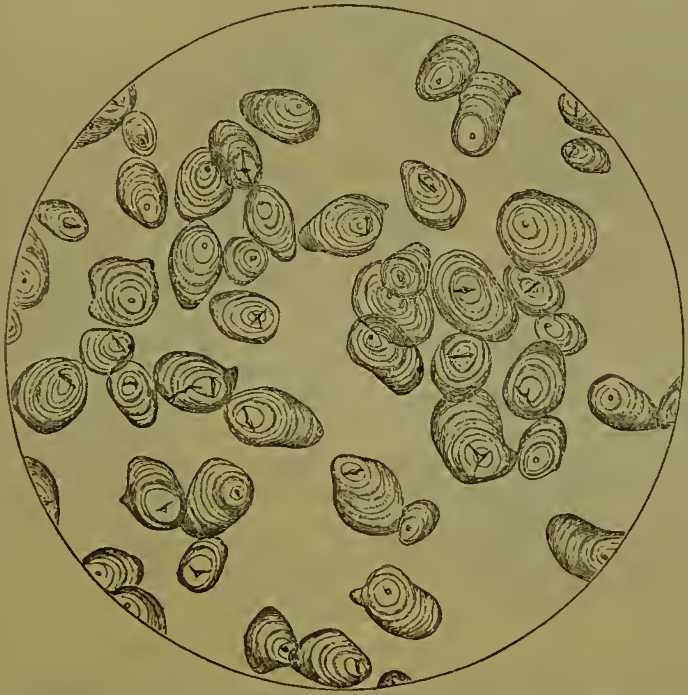
'The starch, or fecula, is extracted from the roots (tubers), when these are about ten or twelve months old. The process is entirely a mechanical one, and is performed either by hand or by machine.

'In Jamaica it is procured as follows:—The tubers are dug up, well washed in water, and then beaten in large, deep, wooden mortars to a pulp. This is thrown into a large tub of clean water. The whole is then well stirred, and the fibrous part wrung out by the hands and thrown away. The milky liquor being passed through a hair sieve, or coarse cloth, is suffered to settle, and the clear water is drained off. At the bottom of the vessel is a white mass, which is again mixed with clean water, and drained; lastly, the mass is dried on sheets in the sun, and is pure starch.

'In Bermuda the roots are first deprived of their paper-like scales, and then rasped by a kind of wheel rasp, and the fecula well washed through sieves and carefully dried.

'Upon the Hopewell estate, in the island of St. Vincent, the carefully skinned tubers are washed, then ground in a mill, and the pulp washed in tinned copper cylindrical washing-machines. The fecula is subsequently dried in drying houses. In order to obtain the fecula free from impurity pure water must be used, and great care and attention paid in every step of the process. The skinning or peeling of the tubers must be performed with great nicety, as the cuticle contains a resinous matter, which imparts colour and a disagreeable flavour to the starch. German silver palettes are used for skimming the deposited fecula, and shovels of the same metal for packing the dried fecula. Th drying is effected in pans covered by white gauze, to exclude dust and insects.'

Fig. 110.



Starch granules of MARANTA arrowroot, called commonly West India arrowroot. Drawn with the Camera Lucida, and magnified 240 diameters.

The root furnishes, according to Benzon, about 26 per cent. of starch.

Pure and unadulterated Maranta arrowroot should be of a dull and opaque white colour, crepitating or crackling when pressed between the fingers, and treated with about twice its weight of concentrated hydrochloric acid it should yield an *opaque* paste.

The above characters and appearances may all, however, be assumed by certain of the other arrowroots; the microscope, therefore, affords the only ready and certain means of distinguishing this arrowroot from all other species, and these again from each other.

Characters of the starch corpuscles.—Examined with that instrument the granules or particles of Maranta arrowroot are found to be usually more or less oblong and ovate, but sometimes they are mussel-shaped or even almost triangular; they vary considerably in size, but each of the larger granules is marked by a number of delicate concentric lines; at the broad or large extremity of each a distinct spot is visible, ordinarily considered to be a cavity, and denominated the 'hilum;' this spot is sometimes circular, but most frequently it is seen as a short, sharp line, running transversely across the granule; it furnishes a most distinctive feature by which Maranta arrowroot may be at all times very readily identified (fig. 110).

When boiling water is added to Maranta or any other arrowroot, its physical condition undergoes a great and surprising alteration, the nature of which may be clearly traced by means of the microscope. A tablespoonful of arrowroot, on which a pint of boiling water is poured, immediately loses its whiteness and opacity, becomes transparent, and the entire of the water is as it were converted into a thick and jelly-like substance. If a little of this be diffused through cold water, and examined with the microscope, it will be seen that the starch granules are altered amazingly: they have increased to twenty or thirty times their original volume; they are more or less rounded; the concentric lines and the hilum are obliterated; the membrane of each granule is ruptured, and a granular matter has escaped from its interior.

The appellations which have been bestowed upon Maranta arrowroot are very numerous; their use ought to be wholly discontinued, for the reasons already assigned: thus it is sometimes called West India arrowroot, Jamaica, Demerara, Bermuda, Berbice, St. Vincent arrowroot, &c. The impropriety of denominating it West India arrowroot is shown by the circumstance that the Maranta plant is cultivated in the East as well as in the West Indies.

CANNA, OR TOUS LES MOIS ARROWROOT.

Canna edulis, the plant from the tubers of which the starch known as *Tous les Mois* is obtained, belongs to the natural order *Marantaceæ*, which includes *Maranta arundinacea*, or West India arrowroot.

The starch is obtained much in the same manner as that of the other arrowroots; that is, the tubers are rasped, and the fecula separated from the pulp by washing, straining, decantation of the supernatant liquor, and desiccation of the deposited starch. It is imported from St. Kitts.

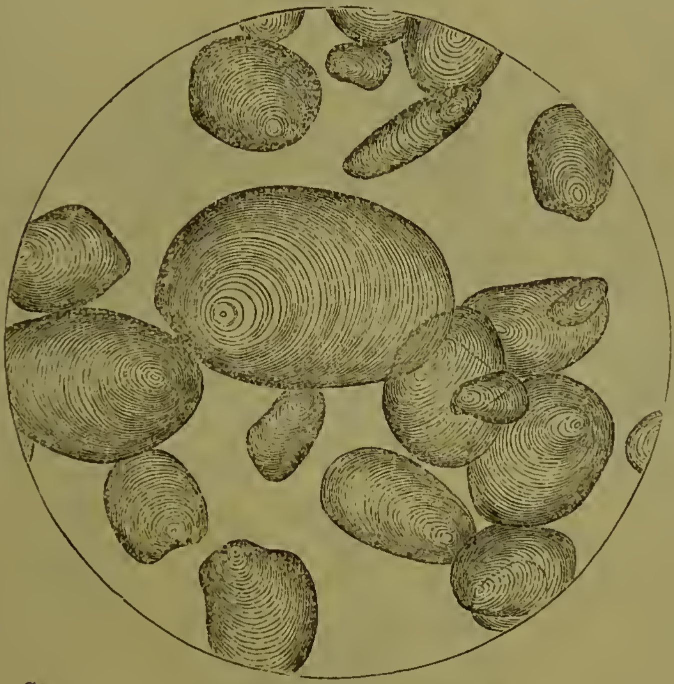
The jelly yielded by it is said to be more tenacious, but less clear and translucent, than that of other arrowroots.

Owing to their large size, the starch granules exhibit a glistening or satiny appearance; they differ from other dietetic starches not only in their much greater dimensions, but in certain other particulars.

Characters of the starch corpuscles.—The granules or corpuscles are nearly all very large, flat, broad, but ovate; sometimes, like those of East India arrowroot, pointed at the narrow end. The hilum is situated in the narrow extremity of the granule, and the rings are exceedingly fine, regular, and crowded (fig. 111).

The only starch with which they are at all likely to be confounded is that of the potato; the granules are, however, larger, of a different shape, being flat, and the striæ are much more regular and numerous.

Fig. 111.



Canna, or *Tous les Mois* arrowroot. Magnified 225 diameters.

Viewed by polarised light the crosses are more regular than in potato starch.

CURCUMA ARROWROOT.

Curcuma arrowroot is obtained from the tubers of *Curcuma angus- ifolia*, one of the family of the *Zingiberaceæ.*

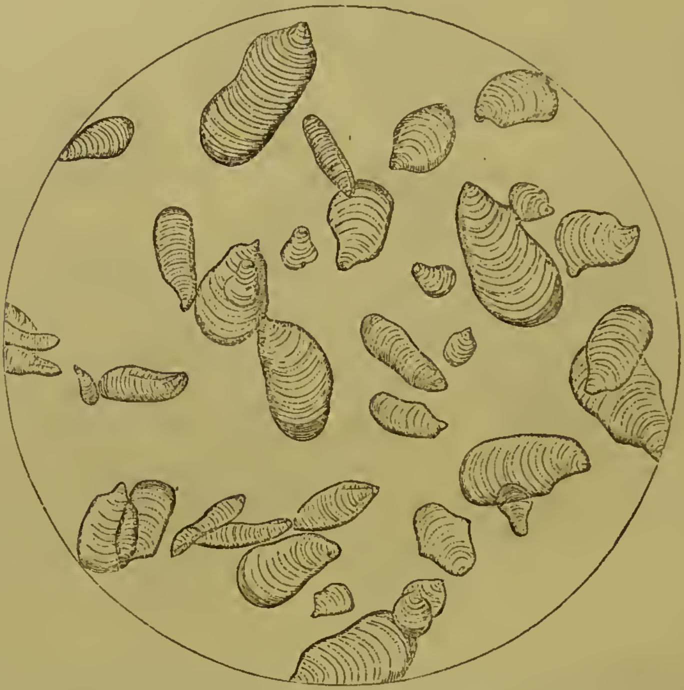
The mode of its preparation does not differ materially from that ractised in obtaining the fecula from the tubers of *Maranta arun- linacea*, and which has already been described.

Two qualities of Curcuma arrowroot are imported into this country from the East Indies, principally from Calcutta, a white and a brown variety.

The white is the best; the powder, when pressed between the fingers, feels less firm, and does not crepitate to the same extent as Maranta arrowroot; the two species can, however, be distinguished from each other only with certainty by means of the microscope.

Characters of the starch corpuscles.—Examined with that instrument, the granules appear elongated, and are irregularly ovate; being flat, they present but little lateral shading; the lines which mark the surface are tolerably distinct, but they describe segments of circles only, and the hilum, which is usually very indistinct and sometimes invisible, is placed at the narrow extremity of each granule. In size the particles vary considerably, but many of them much exceed the largest contained in Maranta arrowroot (fig. 112).

Fig. 112.



CURCUMA arrowroot, commonly denominated East India arrowroot. Drawn with the Camera Lucida, and magnified 240 diameters.

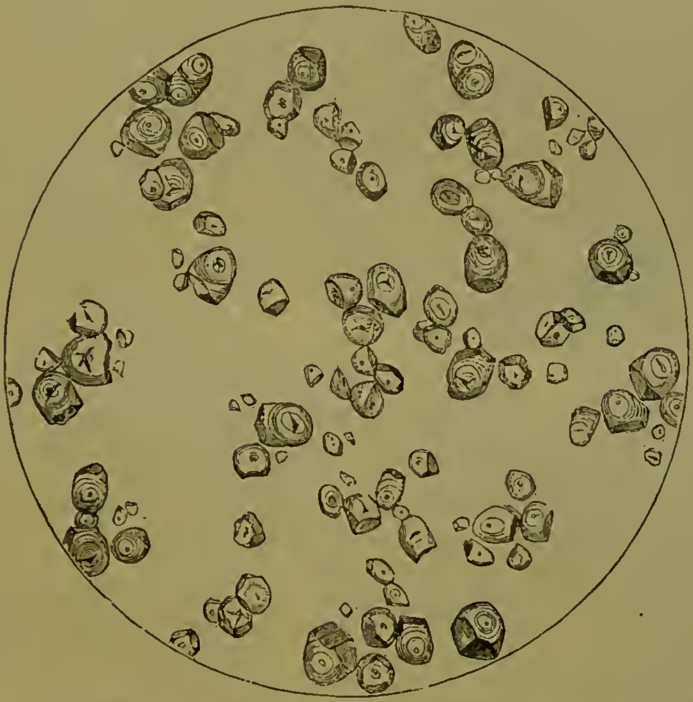
Curcuma arrowroot, therefore, is distinguished from Maranta arrowroot by the size and form of the granules, the position of the hilum, and the incomplete rings seen on the surfaces of the granules.

Curcuma arrowroot is commonly called East India arrowroot, the same name being sometimes applied to Maranta arrowroot cultivated in the East, and sent to this country; we have thus two distinct species of arrowroot, of different qualities and value, confounded together under one name.

TACCA ARROWROOT.

Tacca arrowroot is obtained from the tubers of *Tacca oceanica*, a native of the South Sea Islands, after the chief of which, Tahiti or Otaheite, it is usually designated.

Fig. 113.



TACCA arrowroot, called usually Tahiti or Otaheite arrowroot. Drawn with the Camera Lucida, and magnified 220 diameters.

According to Ellis,[1] it grows on the high sandy banks near the sea, or on the sides of the lower mountains.

In Pereira's 'Elements of Materia Medica' the following account is given of the preparation of the fecula:—'At Tahiti this is procured by washing the tubers, scraping off their outer skin, and then reducing them to a pulp by friction on a kind of rasp, made by winding coarse twine (formed of the cocoa-nut fibre) regularly round a board.[1] The pulp is washed with sea water through a sieve, made of the fibrous web which protects the young frond of the cocoa-nut palm. The strained liquor is received in a wooden trough, in which the fecula is deposited; and the supernatant liquor being poured off, the sediment is formed into balls, which are dried in the sun for twelve or twenty-four hours, then broken and reduced to powder, which is spread out in the sun to dry.'

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[1] 'Polynesian Researches.'

Tacca arrowroot is a white, starch-like powder, having a slightly musty odour.

Characters of the starch corpuscles.—The granules resemble somewhat those of sago meal, but are very much smaller; when viewed sideways, they are muller-shaped, with truncate or dihedral bases, and when seen endways they appear circular, and occasionally angular or polyhedral. The rings are few and indistinct, and the hilum circular, sometimes fissured in a stellate manner (fig. 113).

Tacca arrowroot was sold in London for some years, in packages, as 'arrowroot prepared by the native converts of the missionary stations in the South Sea Islands.' It is sometimes spoken of as 'Williams's arrowroot,' after the missionary of that name.

The slightly musty odour which it usually possesses shows that it is not in general prepared with quite the same amount of care as is bestowed on Maranta arrowroot.

MANIHOT ARROWROOT.

The flour or farina of *Manihot utilissima*, the plant which yields 'tapioca,' is sometimes imported into this country under the name of 'Brazilian arrowroot.'

To the application of the word arrowroot to the fecula of this plant there exists no objection, since it resembles closely the other arrowroots in its properties.

Manihot utilissima, the Cassava or tapioca plant, and the manner in which the fecula is first obtained, and subsequently converted into the substance called tapioca, will be found described in the report upon 'Tapioca.'

Characters of the starch corpuscles.—Manihot arrowroot, like the other kinds already described, may be distinguished by the size, form, and other characters of its constituent granules, which resemble somewhat closely those of Tacca arrowroot, but are considerably smaller, with a larger proportion of granules, which exhibit a circular outline, as seen in the field of the microscope: the hilum is usually fissured (fig. 119).

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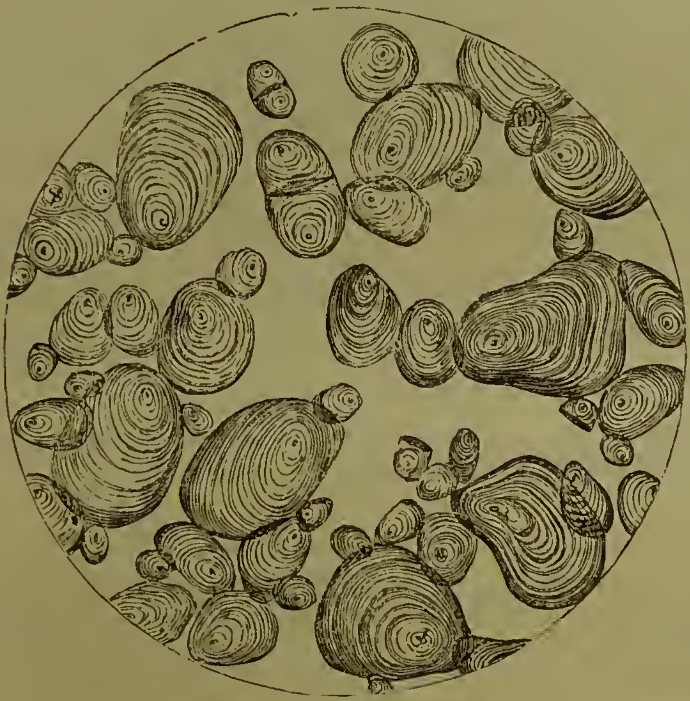
[1] Ellis states that the rind of the root is scraped off by a cowrie shell, and the root then grated on a piece of coral.

POTATO ARROWROOT.

Potato flour, or arrowroot, sometimes called *British* or *English* arrowroot, is prepared by rasping and grinding the well-cleansed tubers of *Solanum tuberosum* into a pulp. This is repeatedly washed, and the water strained through a sieve, which contains the cellular tissue, and allows the starch to pass through. After a time the starch is deposited at the bottom of the vessel, is again well washed, and finally dried.

Fig. 114.



POTATO arrowroot, commonly called British arrowroot. Drawn with the Camera Lucida, and magnified 220 diameters.

Potato starch forms a white and somewhat glistening powder, which crackles like genuine Maranta arrowroot when pressed between the fingers.

Characters of the starch corpuscles.—The granules vary greatly in size and shape: some are very small and circular, others large, ovate, or oyster-shaped. The larger granules exhibit numerous very distinct concentric rings, and the hilum, which is small, but well defined, is situated in the narrow extremity of each granule: not unfrequently granules may be observed of an oval form, divided by a fine line into two portions or segments, each of which is provided with a hilum.

We have noticed the same compound granule in some of the other arrowroots, particularly the Tacca species.

The granules of potato arrowroot differ from those of the previously described starches in their larger size, in their form, and in the number and distinctness of the concentric rings which each granule presents to view (fig. 114).

No means exist by which potato arrowroot may be distinguished so satisfactorily as by the microscope; yet it is proper to state, it has been observed that this substance is acted upon by certain reagents in a manner different from Maranta arrowroot. Mixed with twice its weight of concentrated hydrochloric acid, Maranta arrowroot yields an opaque paste; whereas that formed with potato arrowroot is transparent and jelly-like. When boiled with water and sulphuric acid the latter evolves a peculiar and somewhat disagreeable odour, which is not the case with the former when treated in the same manner. Lastly, alcohol extracts from potato flour an acrid oil, not contained in the fecula of the Maranta plant.

Potato arrowroot is the cheapest of all the starches regarded as arrowroots, the retail price varying from 4*d.* to 6*d.* per pound. Although a cheap and useful article of diet, it is of course inferior to Maranta arrowroot, the inferiority being in part due to the want of sufficient care and nicety in its preparation.

MAIZE ARROWROOT.

A very excellent arrowroot is largely prepared from *Zea mais,* and sold under the name of *corn flour* (fig. 81).

RICE ARROWROOT.

Another description of arrowroot which has recently come much into use is prepared from rice, *Oriza sativa,* and sold under the name of rice flour. It is largely manufactured by Messrs. J. and J. Colman (fig. 84).

ARUM ARROWROOT.

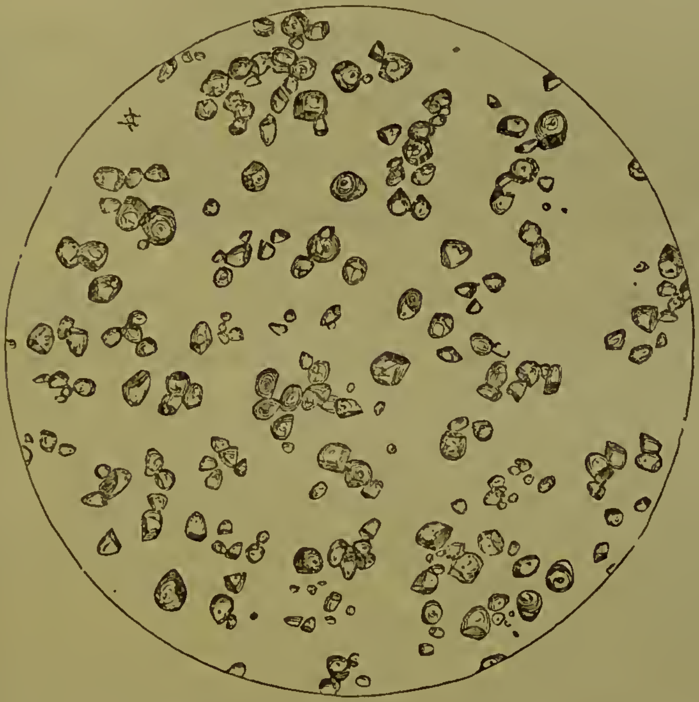
Arum arrowroot is procured from the tubers of *Arum maculatum,* the common 'cuckoo pint,' 'wake robin,' and 'lords and ladies:' it is prepared chiefly in Portland island; hence it is generally called 'Portland arrowroot.'

The mode of its preparation is very similar to that adopted with the other arrowroots; the tubers are pounded in a mortar, the pulp repeatedly washed, and the water subsequently strained. As the tubers are very acrid, great care is required in the washing and straining, so that the acridity may be completely removed.

Characters of starch corpuscles.—The starch granules of Arum arrowroot are very small, and, except in size, they resemble very closely those of Tacca arrowroot; but this difference is sufficiently constant and considerable to ensure the ready identification of the two kinds (fig. 115).

Strictly speaking, the word arrowroot may be applied to every pure starch, that is, every article consisting only of starch the produce of one plant. Now pure starch may be obtained from nearly any grain or plants containing starch in considerable amount, as from *wheat, rye,* &c.; hence we may have arrowroot procured from each of the grains named as well as a variety of others.

Fig. 115.



Arum arrowroot, commonly called 'Portland arrowroot.' Drawn with the Camera Lucida, and magnified 240 diameters.

THE ADULTERATIONS OF ARROWROOT.

The adulterations to which arrowroot is subject consist, first, in the mixing together of arrowroots of different kinds and of different commercial value; and, second, in the admixture with genuine arrowroot of other starches not usually recognised as arrowroot, and of low price; occasionally starches not arrowroots are substituted for arrowroot.

The adulterations of arrowroot are usually practised at home. From evidence kindly furnished us by Mr. Day, of Old Cavendish Street, it appears, however, that not unfrequently it is mixed with inferior starches, as those of potato and sago, in the West Indies.

Results of the examination of samples.—Of *fifty* samples of arrowroot subjected to microscopical examination, no less than *twenty-two* were adulterated.

In *sixteen* samples the adulteration consisted in the addition of a single article, much cheaper in price, and very inferior in quality, to genuine arrowroot, this, in ten instances, being *potato flour*; in five, *sago meal*; and in one case *tapioca starch.*

In *five* samples it consisted in the employment of two different articles, *potato flour* and *sago meal.*

In *two* instances three different starches were employed in the adulteration—viz., *potato flour*, *sago meal*, and *tapioca starch* or fecula.

Ten of the arrowroots *contained scarcely a particle of genuine Maranta or West Indian arrowroot*, for which they were sold. *One* consisted almost entirely of *sago meal*; *two* of *potato flour* and *sago meal*; *two* of *potato flour*, *sago meal*, and *tapioca starch*; *one* of *tapioca starch*; and *four* were composed entirely of *potato arrowroot* or starch.

THE DETECTION OF THE ADULTERATIONS OF ARROWROOT.

The adulterations practised upon arrowroot are all of them readily discoverable by means of the microscope.

The structure and characters of potato starch have already been described and figured at p. 371; those of sago are so at p. 376, and of tapioca at p. 379. The granules of sago starch are of considerable size, either ovate or more usually somewhat muller-shaped, rounded at one extremity, the other being truncated or else terminating in a dihedral summit; the hilum is placed in the larger and rounded part of the granule, is usually surrounded by a distinct ring, and is circular, cracking frequently in a radiate manner (fig. 116).

The strong inducement which exists to substitute potato starch and sago meal for the better descriptions of arrowroot will be evident when it is known that these starches may be purchased wholesale at something like 2*d.* per lb., while as much as 2*s.* 6*d.* and even 3*s.* 6*d.* is charged for the articles so often falsely denominated West India arrowroot.

CHAPTER XV.

SAGO AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any other starch or farina than that of the sago plant, or any added vegetable or mineral substances.

The farinaceous substance known as *sago* is obtained from the pith of the stems of several kinds of palm, as the following:—*Sagus rumphii*, *S. farinifera*, *S. raphia*, *S. laevis*, and *S. genuina*. These palms grow in the islands of the Indian Archipelago, Madagascar, and New Guinea.

Sago is also obtained from *Cycas circinalis* and *Cycas revoluta*, which grow in China and Japan. It is thus prepared:—The pith is stirred up with water on sieves. The starch is thus washed out, and, subsiding from the water, is collected, partially dried, granulated by being passed through sieves, and finally dried either in the air, or in ovens at a temperature of 60° C., whereby the starch granules become altered in form, and the grains are rendered somewhat translucent. The specific gravity of sago varies from 0·670 to 0·776.

Sago is prepared in the forms of *raw sago meal*, *sago flour*, and several kinds of *granulated sago*, as *white*, *red*, *brown red*, *brown*, and *pearl sago*.

Raw sago meal is procured in the Moluccas as follows:—When sufficiently mature the tree is cut down near the root, divided into pieces six or seven feet long, each of which is split down the middle; the pith is then extracted, and, with an instrument of bamboo or hard wood, is reduced to powder like sawdust; it is mixed with water, and the mixture strained through a sieve which retains the cellular tissue of the pith. The strained liquor contains the farina, which, after being deposited, is washed once or twice, and is then fit for use.

Sago flour is prepared from sago meal by repeated sifting and washing; it is also usually bleached by means of chloride of lime.

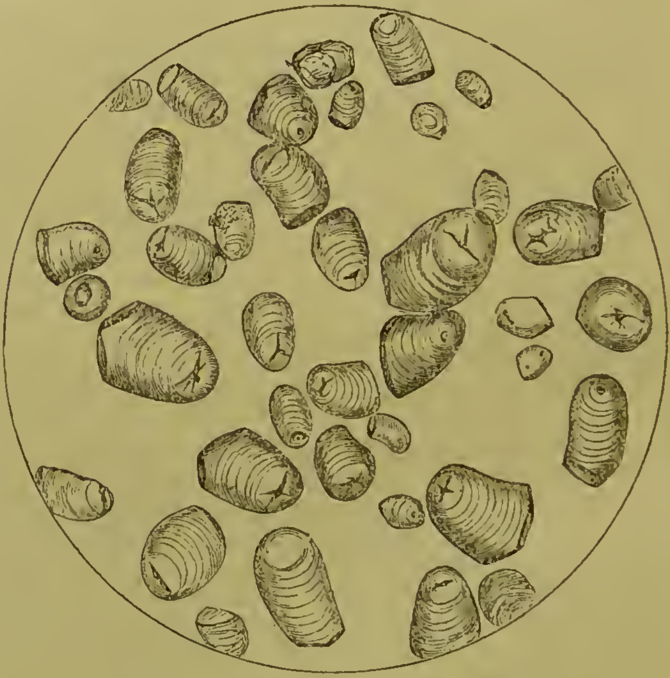
In the countries in which sago palms are produced the pith is eaten, and in some cases, as with the inhabitants of the Moluccas, it constitutes their staff of life.

Characters of the starch corpuscles.—The farina or starch of sago, examined with the microscope, is seen to consist of granules of considerable size and elongated form, being usually rounded at one end which is the larger, and, owing to the mutual pressure of the particles, truncate at the other extremity; the hilum, when perfect, is circular; but it is often cracked, when it appears as a slit, cross, or star. Surrounding the hilum, a few indistinct rings may usually be perceived in some of the granules. Examined with the polariscope, the particles usually exhibit a black cross, the hilum being the centre (fig. 116).

THE ADULTERATIONS OF SAGO.

The principal adulteration of sago flour and of granulated sago is with potato starch. Frequently a factitious sago prepared from potato starch is substituted for true sago.

Fig. 116.



SAGO *Starch.* Magnified 225 diameters.

Pereira has the following remarks in relation to factitious sago:—'This is prepared in both Germany and in France, at Gentilly near Paris, with potato starch. It occurs both white and coloured.

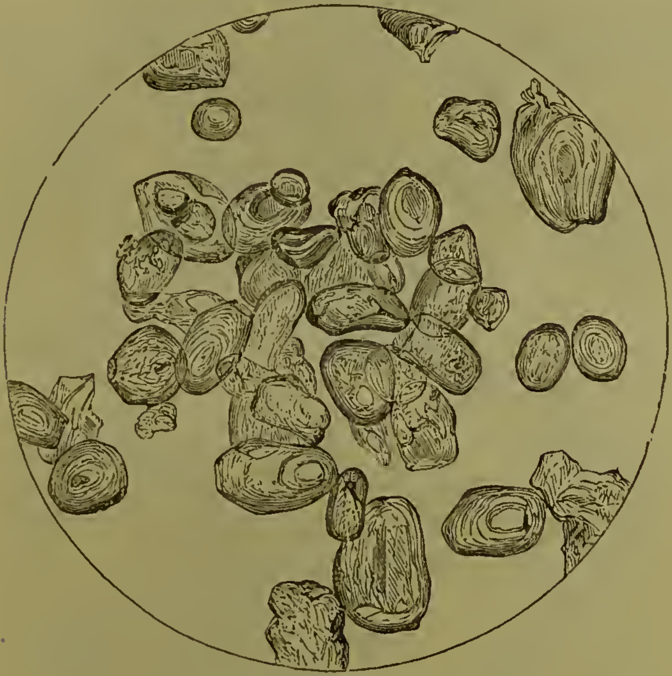
I have two kinds of white factitious sago, one small grained, the grains of which are scarcely so large as white mustard seeds: the other large grained, the grains of which are intermediate in size between white mustard seeds and coriander seeds. The first I met with in English commerce; for the other I am indebted to Professor Guibourt.

'I have also two kinds of coloured factitious sago, both large grained; one red,[1] the other brownish,[2] and somewhat resembling brownish pearl sago.'

Pereira also states that he received from Prof. Guibourt samples of 'Sagou des Maldives de Planche, donné par lui,' and 'Sagou de la Nouvelle Guinée, donné par lui,' and that he found them to be factitious sagos prepared from potato starch. The grains of the New Guinea sago were bright red on one side and whitish on the other.

Results of the examination of samples.—Of *thirty* samples of granulated sago submitted to examination, *five* were found to be *factitious,* and to consist of *potato flour.*

Fig. 117.



Starch granules of SAGO, altered by heat, as in making *granulated sago.* Magnified 225 diameters.

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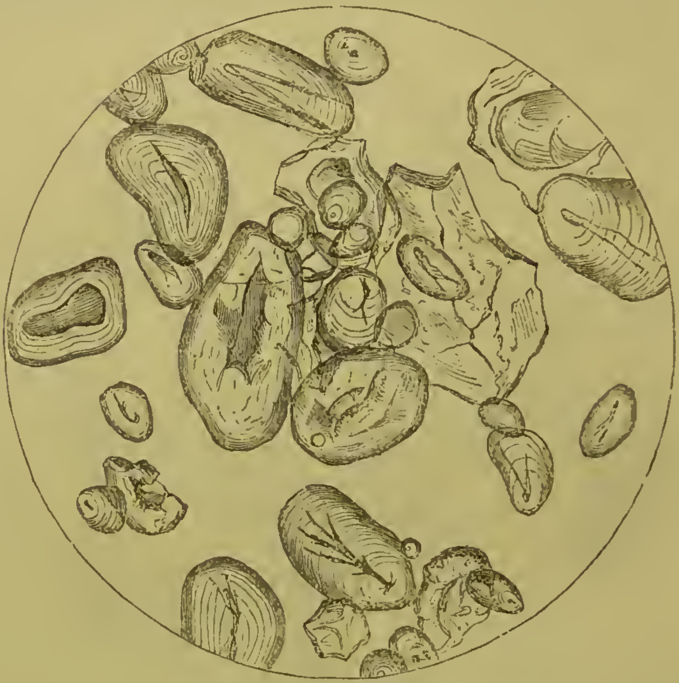
[1] 'This is perhaps the kind mentioned by Planche, as being falsified sago coloured with cochineal.'

[2] 'This is perhaps the brown sort of German sago made from potato starch, and said by Dierbach to be coloured with burnt sugar.'

THE DETECTION OF THE ADULTERATIONS OF SAGO.

The microscope can alone detect the adulterations of sago flour and granulated sago, and especially can distinguish factitious from genuine sago. The characters of sago starch have already been described and figured, as also have those of potato, at p. 371; in granulated sago, whether true or false, the granules are of course much altered (fig. 117); those of potato are swollen, irregular in shape, sometimes ruptured, and the striæ effaced, &c. (fig. 118).

Fig. 118.



Factitious sago, composed of *potato flour*. Magnified 225 diameters.

CHAPTER XVI.

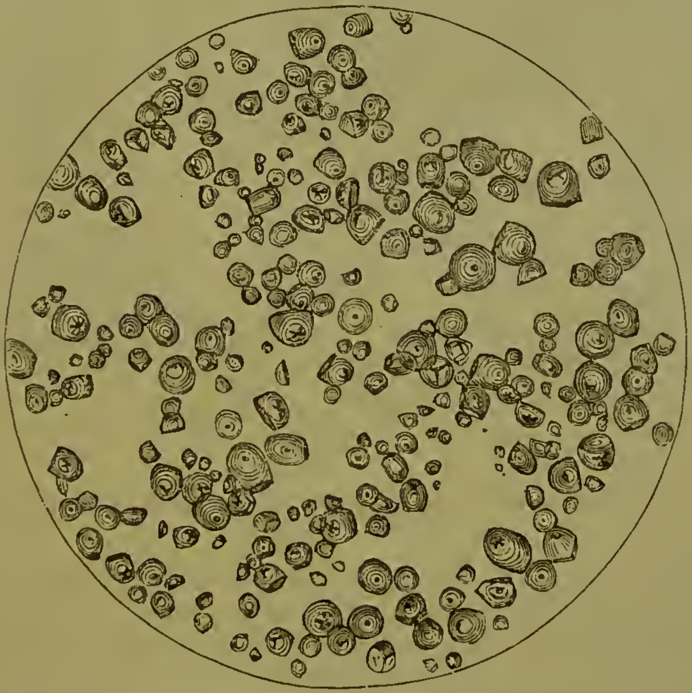
TAPIOCA AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any other starch or farina than that of Tapioca, or any added vegetable or mineral substances.

THE articles known as Cassava meal and bread, Cassava, Tapioca, or Brazilian arrowroot and Tapioca, are obtained from different species of the genus *Manihot*, one of the *Euphorbiaceæ.* One of these is *M. utilissima*, the bitter Cassava, a native of the Brazils, where, as well as in other parts of South America, it is cultivated.

Fig. 119.



Starch granules of MANIHOT UTILISSIMA, or *Tapioca.* Magnified 225 diameters.

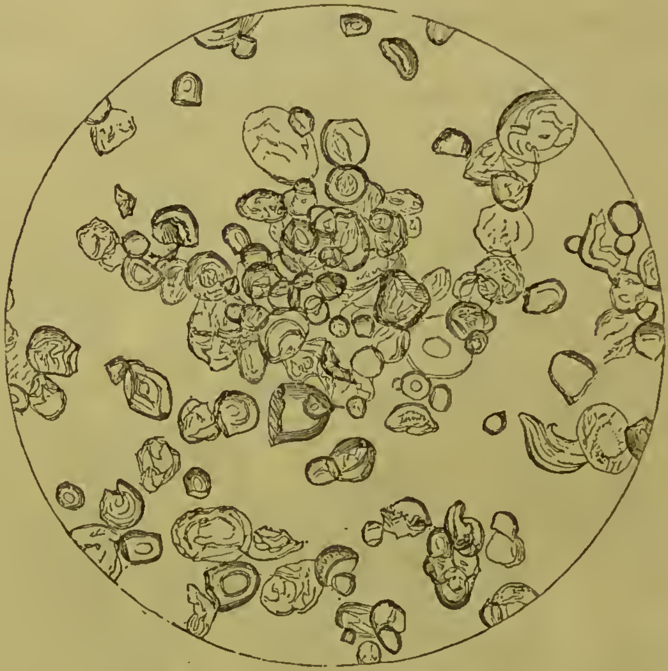
The starch is associated in the large tuberous root with a poisonous milky juice containing hydrocyanic acid and a bitter acrid principle.

Another species is *Manihot Aipi*, or sweet Cassava, the juice of the root of which is not poisonous.

A third species is *M. Janipha*, the root of which is also devoid of poisonous properties.

Cassava meal is prepared as well from the bitter or poisonous species as the sweet and innocuous: the root is grated, and the pulpy mass subjected to pressure in bags under water to get rid of the juice; the residue is spread out on iron plates in layers of one or two inches in thickness, and is dried into cakes, when, after being pounded, it constitutes *Cassava meal*, and of this the bread is made.

Fig. 120.



Starch granules of *Tapioca*, altered by the heat employed in its preparation. Magnified 225 diameters.

The expressed juice deposits after a time the farina or starch, which in this state is called *tapioca meal*, and this, after being dried upon hot plates, constitutes *granular tapioca*.

Characters of the starch corpuscles.—Examined under the microscope, the granules are seen to be of small size, for the most part single, but sometimes and in the plant itself always united into compound grains, each composed of two, three, or four granules. Hence, like those of sago, they are usually muller-shaped, although when seen endways they appear circular; the hilum is distinct. No differences have been observed in the characters of the starch of bitter and sweet Cassava.

Manihot arrowroot is usually imported into this country from Rio de Janeiro.

The farina or starch deposited from the milky fluid, after being carefully washed and dried without the employment of heat, constitutes *Manihot* or *Brazilian arrowroot.* In the manufacture of tapioca, the meal while moist is heated and then dried on hot plates; this treatment, of course, causes the starch granules to swell, and many of them to burst; they at the same time adhere together in small irregular masses.

THE ADULTERATIONS OF TAPIOCA.

Manihot arrowroot or starch is occasionally adulterated by admixture with other starches, as those of *sago* and *potato.*

Results of the examination of samples.—Of *twenty-three* samples of tapioca examined, *two* were ascertained to consist of *sago*, and *one* of *potato starch.*

Manihot starch is more frequently used as an adulterant, especially of Maranta arrowroot, than it is itself adulterated.

THE DETECTION OF THE ADULTERATIONS OF TAPIOCA.

The only means of detecting the adulterations of Manihot arrowroot, and of tapioca, is furnished by the microscope; with that instrument their detection is rendered easy and certain. The characters of *sago starch* are described and figured at p. 376, and those of *potato starch* at p. 371.

CHAPTER XVII.

PROPRIETARY ALIMENTARY PREPARATIONS.

The articles referred to under the above head being proprietary, and there being no recognised receipts or formularies for their composition, they do not properly come under the head of articles of consumption liable to adulteration. Nevertheless, the public will doubtless be glad to be made acquainted with the composition of the chief of these articles, especially those which are described as being possessed of almost miraculous powers of curing disease, and which are sold under certain high-sounding names, and some of them at exorbitant prices. Until the microscope was applied by ourselves to the discrimination of different vegetable substances, it was not possible to have determined, by any known means, the composition of many of the preparations about to be noticed.

The following examinations were made some years since, and it is probable that some of the preparations named are no more to be met with:—

Ervalenta. Sold at 2*s.* 9*d.* per lb.

A sample of this article, examined, consisted of a mixture of *the French* or *German lentil,* with a substance resembling *maize,* or *Indian corn meal.*

It has been stated that the farina of a grass called 'Dari,' 'Durra,' &c., has been discovered in either Ervalenta or Revalenta.

We have succeeded in procuring a sample of this article, and find it to resemble very closely maize in structure.

'Dari' is occasionally imported into this country, and sold at about twenty-four shillings per quarter, that is, at the rate of rather more than one halfpenny per pound.

We received from Dr. Pereira, some time previous to his decease, the following information respecting 'Durra.'

'*Dari* I suspect means *Durra,* also spelt *Doura, Dora,* &c. It is a corn used by the Arabs, and is cultivated in the south of Europe. It is the *Holcus Durra sativus* of Förskäl, the *Sorghum vulgare* of some other writers.

'Its meal is said to resemble that of Indian corn. Now, it deserves notice, that a German microscopist recently stated that he found the meal of Indian corn in *ervalenta,* or *revalenta,* I forget which. Did he mistake it for the Sorghum?'

For description and figure of Durra, see p. 328, and fig. 101.

Revalenta. Sold at the same rate as the Ervalenta.

Three samples of this article were examined: one consisted of a mixture of the *red* or *Arabian* lentil and *barley flour*; the second, of the same ingredients mixed with *sugar*; and the third sample consisted of the *Arabian lentil* and barley flour, with the addition of saline matter, chiefly *salt*; it also possessed a peculiar taste, as though flavoured with *celery seed.*

Butler & M'Culloch's Prepared Lentil Powder, 1*s.* 6*d.* per lb., was found to consist entirely of the *French or German lentil.*

Arabian Revalenta, 1*s.* per lb., was ascertained to consist of *lentil powder*, probably of the yellow and red lentil mixed.

Patent Flour of Lentils, 1*s.* per lb. Two samples of this article were examined: one consisted of the *red lentil* and *wheat flour*, and the other of the same species of *lentil* and *barley flour.*

Lentils belong to the natural family of plants, *Leguminosæ*, which includes the several kinds of beans and peas; they resemble, to a very great extent, in colour, structure, taste, and properties, the common pea; so great, indeed, is the similarity in organisation, that it is difficult to discriminate between them, even by the aid of the microscope.

Lentils, peas, beans, &c., all contain a considerable amount of nitrogenised matter, in the form of *Legumin.*

The composition of peas, beans, and lentils is exhibited in the following tables:—

	Poggiale. Air-dried and shelled green Peas.	Poggiale. Air-dried common white field Beans
Water	12·7	19·3
Starch, dextrin, and sugar .	57·7	45·4
Legumin	21·7	22·8
Fatty matter . . .	1·9	2·7
Cellulose	3·2	6·2
Mineral matter . . .	2·8	3·6
	100·0	100·0

Lentil. (Fresenius.)

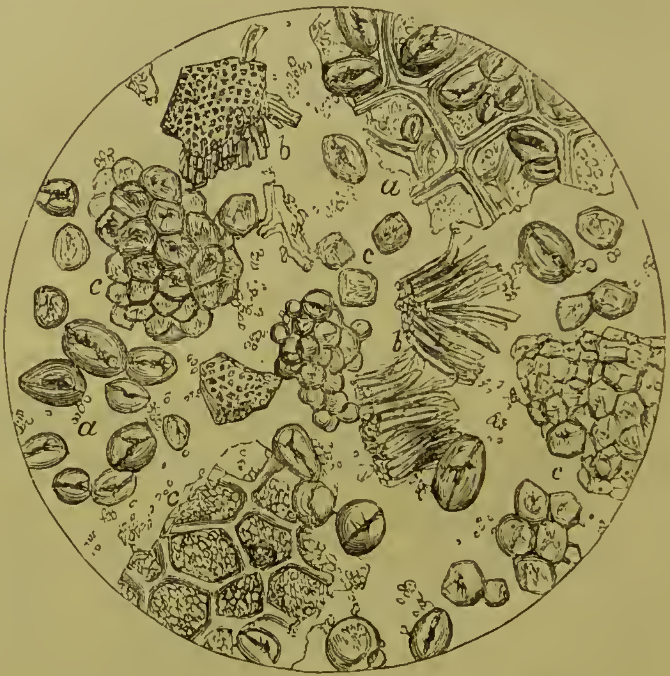
Water	14·0
Starch	35·5
Gum	7·0
Sugar	1·5
Legumin	25·0
Fat	2·5
Cellulose, Pectin, &c.	12·0
Mineral matter	2·5
	100·0

When taken as an article of diet, lentils, peas, and beans are found by most to be somewhat difficult of digestion, to occasion distension and flatulency, and to be slightly aperient. These properties and effects are so similar in the case of each, that it is almost impossible to draw any decided line of demarcation between them.

The admixture of barley and other flours with lentil powder is not to be regarded in the light of an adulteration, since the cost of barley flour exceeds that of the lentil.

The object of this mixture is chiefly to diminish the strong flavour of the lentils, which is so disagreeable to many.

Fig. 121.



Sample of Ervalenta, as it appears under the microscope.

a a, starch corpuscles of the French lentil; *b b*, fragments of the husk; *c c*, starch granules and masses of the substance resembling Indian corn meal.

Extremes meet: lentils, being somewhat cheaper than peas, are supplied to many of our workhouses, to be used in the preparation of soup, &c. Thus they are not only consumed by paupers, but by the rich, the chief difference being that the latter frequently pay 2*s.* 9*d.* per pound for them.

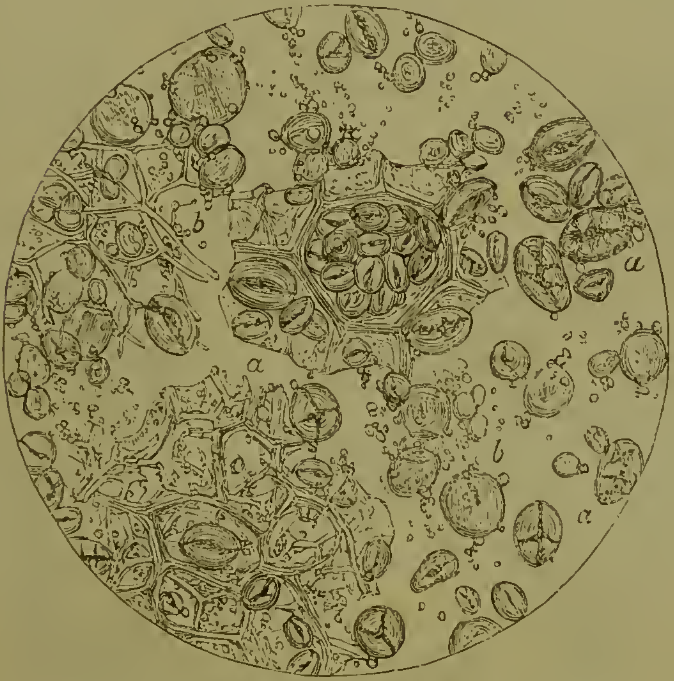
As the cost of most of the prepared lentil powders, sold as Ervalenta, Revalenta, &c. forms a very serious obstacle to their use, supposing that in any respect it is desirable that they should be more generally consumed, we have framed the two following receipts, whereby a considerable saving of expense may be effected:—

1st Receipt.

Red or Arabian lentil flour . . .	2 lbs.
Barley flour	1 lb.
Salt	3 oz.

Mix into a uniform powder.

Fig. 122.



Sample of Revalenta Arabica.

a a, starch granules of the Arabian lentil, some loose, others lying in the cells of the cellulose; *b b*, starch granules of barley flour.

The red lentil may be obtained of almost every corn-chandler, at about 4*d.* per quart: the cost of a pound of *our* Ervalenta would be about 2*d.* per pound; and it is perfectly clear, from the analyses which we have given above, that whatever may be the advantages possessed by the much-vaunted Ervalentas, Revalentas, &c., our article must contain them all.

2nd Receipt.

Pea flour	2 lbs.
Indian corn flour	1 lb.
Salt	3 oz.

Mix as before.

Being satisfied that lentils and peas do not differ in their properties to any great extent, we have devised the above receipt to meet those cases in which any difficulty may be met with in procuring the red lentil, which, however, is now very commonly kept by corn chandlers.

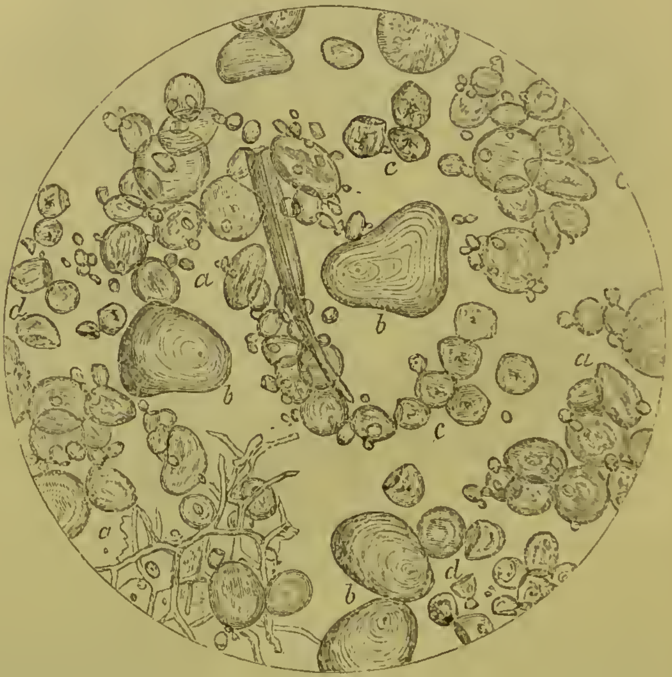
The characters of lentil flour, and the composition of Ervalenta, Revalenta, and of Leath's Alimentary Farina, are exhibited in the engravings (figs. 122 and 123).

From the several preparations of lentil flour noticed, we will pass on to describe certain other

FARINACEOUS FOODS.

Gardiner's Alimentary Preparation consisted of very finely ground *rice*.

Fig. 123.



LEATH'S ALIMENTARY FARINA, OR HOMŒOPATHIC FARINACEOUS FOOD.
a a, starch granules of WHEAT; *b b*, starch corpuscles of POTATO; *c c*, ditto of INDIAN CORN MEAL; *d d*, ditto of TAPIOCA.

Leath's Alimentary Farina, or *Homœopathic Farinaceous Food*, consisted principally of *wheat flour*, slightly baked, sweetened with *sugar*. together with *potato starch*, *Indian corn meal*, and *tapioca*.

Semolina consists in some cases of the gluten of wheat mixed with a proportion of wheat flour; in others, of certain descriptions of wheat flour only, rich in gluten.

Bullock's Semola consisted of the *gluten of wheat* with a proportion of *wheat starch*.

Prince Arthur's Farinaceous Food was composed entirely of *baked wheat flour*.

The Prince of Wales's Food was composed entirely of *potato flour*.

Hards' Farinaceous Flour, of *wheat flour, baked*.

Maidman's Nutritious Farina consisted entirely of *potato flour* artificially coloured of a pink or rosy tint, the colouring matter being probably *rose pink*.

Braden's Farinaceous Food consisted of *wheat flour, baked*.

Baster's Soojie was composed of *wheat flour*, sweetened with *sugar*.

Baster's Compounded Farina possessed *a similar composition*.

Jones's Patent Flour consisted of *wheat flour, tartaric acid*, and *carbonate of soda*.

Plumbe's Improved Farinaceous Food was composed of *bean* or *pea flour*, with a little *Tacca arrowroot*, some *potato flour*, and a very little *Maranta arrowroot*.

Lastly, *Palmer's Vitaroborant* consisted of a mixture, sweetened with sugar, of the *red* or *Arabian lentil* and *wheat flour*.

The public are now in a position to judge of the degree of relation which exists between the high-sounding titles bestowed on many of the preparations noticed in this report, their actual composition, and the properties, so loudly vaunted, alleged to be possessed by them; they will also be able to judge somewhat of the extent to which the pocket is made to suffer through these health-restoring, life-prolonging, easily digestible articles and compounds.

THE DETECTION OF THE COMPOSITION OF PROPRIETARY ALIMENTARY PREPARATIONS.

In the majority of cases the only means by which the composition of these articles is to be determined is afforded by the microscope. By this instrument the starches of the several flours and arrowroots of which they are composed can all be identified. The characters of nearly all these have already been described and figured.

CHAPTER XVIII.

MILK AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

In Milk.—Any foreign animal, vegetable, or mineral substance, or added water; or the removal of any portion of the fatty matter or cream.

In Cream.—Casein beyond 8 per cent., water over 55 per cent., or any foreign substance whatever; it should not yield a less proportion than 35 per cent. of fatty matter.

Milk is an opaque, white, yellowish white, or bluish white, bland and slightly sweet liquid, having in general an alkaline reaction and a somewhat variable specific gravity.

When allowed to stand at rest for some time a stratum of a more or less yellow colour collects on the surface, the portion below becoming of a bluish-white colour and of a higher specific gravity. This stratum contains the greater part of the *fat* of the milk, together with a little casein, sugar, and water, and it constitutes the *cream* of milk.

After a time, varying with the temperature, milk acquires an acid reaction from the decomposition of a portion of the *milk sugar* or *lactose*, *lactic acid* being formed; this acid causes the precipitation of the *casein*, which carries down with it nearly the whole of the fat still remaining in suspension. By boiling the milk the conversion of the sugar and the precipitation of the casein are retarded: but milk is quickly coagulated by rennet, sometimes without the production of an acid.

COMPOSITION OF MILK.

Milk consists of *water* holding in solution *casein*, *albumen*, and according to Millon, a third albuminous substance termed *lacto-protein*, in smaller amount than the albumen, *lactose* or *milk sugar*, various *salts*, including especially *phosphate of lime*, and in suspension innumerable *fat globules*, which add to its whiteness and opacity.

Examined with the microscope, myriads of these fat globules, of a beautifully rounded form, and reflecting the light strongly, become visible, as well as sometimes *mucus globules* and *epithelium cells*.

In decomposed or diseased milk *infusoria* or *fungi* are sometimes found, especially in *blue* milk, the colour of which is ascribed by Fuchs to the presence of a vibrio, which he has denominated *Vibrio cyanogeneus*, but Bailleul ascribes it to a byssus.

Skim-milk, butter-milk, cream, butter, curds-and-whey, cream-cheese, and ordinary cheese, are mere modifications of milk, differing only from each other either in the abstraction of one or more of its constituents, or else in the variations of their proportions.

Skim-milk.—The first of these (skim-milk) differs from ordinary milk in containing a less quantity of fatty matter, a portion of this having been removed as cream; it still, however, contains nearly all the cheese, the sugar of milk, some butter, and the salts of milk; it is therefore scarcely less nutritious than new milk, but, in consequence of the diminished amount of fatty matter, is less adapted to the development of fat, and to the maintenance of respiration and the temperature of the body. In some cases where fatty matter is found to disagree, and where, in consequence, milk in its usual state cannot be taken without inconvenience, skim-milk may be substituted with advantage.

Butter-milk.—This is the liquid which remains after the operation of churning, and it approaches skim-milk in its composition, but contains even a smaller quantity of fat; as an article of diet for poor persons, it has the recommendation of cheapness.

Potatoes and butter-milk, as is well known, taken together, form a very considerable portion of the diet of the peasantry of Ireland: the butter-milk constitutes an essential part of such a diet, it supplying the nitrogenised matter necessary for the growth of the body, and of which the potatoes themselves are comparatively deficient.

Cream.—In contradistinction to these, cream consists almost entirely of the fat, with a variable quantity of the water, sugar, and casein of milk.

Butter differs but little from cream, but the fatty matter is altered in its condition. The fat globules, in place of being free, are united together so as to form a semi-solid substance. It contains much less water than cream, but retains some casein, with a very small quantity of lactose.

Curds-and-whey.—Curds-and-whey are made up of all the elements of milk, but the form in which they exist is altered; the casein is thrown down by rennet, or by the addition of an acid, as acetic acid, and, in its descent, it carries with it the greater part of the butter, the two together forming the curd; while the whey, or serum, consists almost entirely of water, the sugar, and the salts.

Cream-cheese.—Cream-cheese consists of the moist curd (that is, of the cheese and butter), the greater part of the serum, or whey, being removed by slight pressure.

Ordinary cheese.—Ordinary cheese contains little or much butter, according as it is made from skim or from whole milk; the casein is precipitated by rennet in the usual manner, and subjected to great pressure in moulds. *Annatto* is frequently added to heighten its colour, and the cheese is kept until it becomes more or less ripe.

The relative proportions of the different constituents of cow's milk, especially the fatty matter, are subject to very great variation: the age of the cow, the time after calving, food, temperature, weather, and the time and frequency of milking, all occasion considerable differences.

The constituents of cow's milk in the normal state, according to MM. O. Henrie and Chevalier, are as follow:—

Casein	4·48
Butter	3·13
Sugar of milk	4·77
Salts, various	0·60
Water	87·02
	100·00
Total solids	12.98

The following is the mean of ten analyses of pure milk by Professor Poggiale:—

Water	862·8
Butter	43·8
Sugar of milk	52·7
Casein	38·0
Salts	2·7
	1000·0
Total solids	13·72

Taking all the reliable analyses of cows' and human milk we have met with, we find their average composition to be as stated below:—

	Cow.	Human.
Water	86·83	88·35
Sugar	4·53	4·37
Casein	4·14	3·15
Fat	3·93	3·87
Mineral matter	0·67	0·26
Total solids	13·17	11·65

Casein, which is the chief nitrogenised constituent of milk, is said to exist in two forms, as *soluble* and *insoluble* casein, but it is very questionable whether there is any essential difference between the two kinds, and it appears to be highly probable that the former owes its solubility to the presence of the alkaline phosphates.

Casein in solution is not precipitated by heat, but is coagulated by alcohol, which at the same time dissolves a portion of it, and a still larger quantity if the alcohol be boiled. The precipitate produced by absolute alcohol is completely insoluble in water. Casein is precipitated by all acids, except the carbonic, it being redissolved in an excess of acid. Mineral acids precipitate casein from its acetic acid solution.

The spontaneous coagulation of milk is due, as already noticed, to the decomposition of the milk sugar and the formation of lactic acid. The acid neutralises the alkali by which the casein was dissolved, thus reducing it to the insoluble condition.

Casein contains the same amount of nitrogen, namely, 15·8 per cent., as do the other albuminoids. It contains about 1 per cent. of sulphur, and is said to be intimately combined with phosphate of lime.

Coagulated casein is readily soluble in the caustic alkalies; when boiled with a solution of potash, sulphide of potassium is formed. Fused with potash, ammonia is first evolved and then hydrogen, with the formation of tyrosin, leucin, valerate, butyrate and oxalate of potash, also with a salt the acid of which is volatile and possesses an excrementitious odour.

Casein neutralises the alkali of weak solutions. It dissolves in a solution of phosphate of soda, also neutralising it. It is likewise soluble in solutions of the alkaline carbonates, chloride of sodium and chloride of ammonium. These solutions are not coagulated by heat, but become gradually covered with a film which is insoluble in dilute acids and alkalies, the film which forms on milk when it is boiled, having, it is said, the same origin and properties.

Solutions of casein are precipitated by earthy and metallic salts. Insoluble compounds are obtained by boiling casein with the carbonates of lime and barium.

It was formerly believed that the coagulation of milk by rennet was due to the animal matter contained in it acting as a ferment, and thus bringing about the conversion of the milk sugar into lactic acid, milk thus coagulated always exhibiting an acid reaction. It has since been shown, however, that milk may be coagulated by rennet, when its solution is rendered alkaline, the milk still remaining alkaline after the coagulation.

Moist casein soon undergoes putrefaction, yielding sulphide and carbonate of ammonia, which dissolve a portion of the undecomposed casein. It also furnishes butyric and valeric acids, an oily body having a highly disagreeable odour, and, according to Bopp, a crystalline body possessing a powerful smell.

When casein undergoes putrefaction without access of air, it yields acetic, butyric, valeric and capric acids, as also ammonia.

According to the analyses of Clemm, Haidlen, Vernois, and Becquerel, the casein of human milk varies from 2·7 to 3·924, while, according to Boussingault, Playfair, Vernois, and Becquerel, that of the cow varies from 3·0 to 5·52 per cent.

When milk is introduced into the stomach the casein is coagulated by the acids of the gastric juice before it is digested.

Milk contains, besides casein, a second nitrogenous substance, namely, *albumen*, and, according to Millon, even a third, *lacto-protein*. If the milk, after the removal of the casein by as small a quantity of acetic acid as will answer the purpose, be boiled, the albumen will be thrown down and may be separated by filtration. Heinsius found 1·5 per cent. of albumen in cow's milk, after the precipitation of the casein by acetic acid and boiling. It was formerly believed that the scum which forms when milk is boiled was composed of albumen, but from observations since made, this scum would appear to consist, as already noticed, of casein in a modified form.

Milk sugar, lactin, or *lactose,* $C_{12}H_{22}O_{11}$, belongs to the group of fermentable sugars. It crystallises in hemihedral, trimetric crystals; it is less sweet and not as readily fermentable as cane sugar. It dissolves in from 5 to 6 parts of cold water and in 2½ parts at the boiling temperature. A solution, saturated at 10° C., has a specific gravity of 1·055 and contains 14·55 per cent. of crystallised milk sugar, which contains in this state 1 molecule of water, which it retains up to 130° C.

The aqueous solution is dextrorotatory, turning the plane of polarisation, according to Berthelot at 59·3 and to Biot at 60·28 degrees.

Lactose is insoluble in alcohol and ether, but soluble in aqueous solutions of acetic acid.

It forms compounds with potash, soda and ammonia, the alkaline earths, and with oxide of lead.

When heated to 160° C. it turns brown, and at 175°C. it is converted into *lacto-caramel* with loss of water.

By prolonged boiling with water, or quicker with dilute sulphuric acid, it is converted into *galactose*, $C_6H_{12}O_6$, which stands in the same relation to lactose as does inverted sugar to saccharose or cane sugar.

The strong mineral acids and alkalies decompose it, especially when their action is aided by heat.

It is easily decomposed by oxidising agents, it reduces silver from its solutions, and throws down from an alkaline copper solution the suboxide of copper.

Distilled with sulphuric acid or peroxide of manganese it yields formic acid, and with nitric acid, mucic, saccharic, tartaric, racemic and oxalic acids.

Milk sugar is less susceptible of fermentation than glucose or saccharose, it not passing into the alcoholic fermentation until some time after it has been brought into contact with yeast. When cheese or gluten is employed as a ferment, the sugar is in part converted into lactic acid, alcohol being at the same time formed.

The sugar, of all the constituents of milk, is least liable to vary in quantity.

Preparation of milk sugar.—The curd and fat are precipitated from milk by means of dilute sulphuric acid or by rennet. The serum or whey is filtered and evaporated until crystals are produced. For their purification the crystals are redissolved in water, the solution filtered through animal charcoal and evaporated till crystals are again obtained, when, in order to procure them in the highest state of purity, they should be precipitated from their aqueous solution by means of alcohol. Milk sugar is prepared, particularly in Switzerland, on a large scale, from the whey left in the manufacture of cheese.

The *fat of milk* consists of solid and liquid fats, the former being *palmitin* and *stearin*, and the latter *olein, butyrin,* and other glycerides of *volatile* acids. They are the glyceryl ethers of the corresponding fatty acids, and yield, when saponified with caustic potash, glycerine and salts of the following acids: *stearic, palmitic, oleic, capric, caprylic, caproic,* and *butyric* acid, and, according to Chevreul, *myristic* acid.

Butter fat becomes rancid on exposure to the air. It dissolves in 28·9 parts of boiling alcohol of specific gravity 0·822.

According to my experiments, to be more fully noticed in the next article, on the adulteration of butter, butter fat has a mean fusing point of 33·7° C.

The average percentage amount of fat in the milk of the cow is 3·98, according to the experiments of Simon, Chevalier, and Henrie, Boussingault, Poggiale, and Becquerel, whereas, according to Simon, Clemm, Chevalier and Henrie, Vernois and Becquerel, the average of the fat in human milk is considerably less, namely, 3·38.

Mineral matter.—According to Vernois and Becquerel, the ash of cow's milk varies from 0·55 to 0·85 per cent., the quantity of soluble salts being generally about the same as the insoluble. According to Weber, the ash of cow's milk has the following percentage composition:—

Potash	23·46
Soda	6·96
Lime	17·37
Magnesia	2·20
Phosphoric acid	28·40
Chloride of sodium	4·74
Chloride of potassium	14·18
	97·31

The carbonic and sulphuric acids are not estimated, and would make up the deficiency.

Vernois and Becquerel give the following as the percentage composition of the ash of human milk:—

Carbonate of lime	6·9
Phosphate of lime	70·6
Chloride of sodium	9·8
Sulphate of sodium	7·4
Other salts	5·3
	100·0

It thus appears that phosphate of lime is the chief constituent of the ash, but the soluble portion also contains *chloride of potassium* and *alkaline phosphates,* and the insoluble part some *phosphate of magnesia* and a little *oxide of iron.*

It will thus be seen from the analyses given that milk contains all the elements necessary to the growth and sustenance of the human body. This view is not only established by the composition of milk, but by the fact that persons are frequently sustained upon a diet of milk for an indefinite period. Milk is, in fact, the best type known of a perfect food.

Total solids of milk.—The analyses of Messrs. Henrie and Chevalier give the solids as 12·98 per cent., and without fat 9·85. The ten analyses of Poggiale furnish a mean of 13·72, and of solids, not fat, 9·34 per cent. Wanklyn gives the total solids of milk, of average quality, in 100 cc. at 12·81 grammes, and of exceptionally rich milk of stall-fed cows at 14·47, and the total solids, not fat, ·9·65 and 10·35 respectively, and he takes the amount of solids, not fat, in normal country milk, namely 9·3, as a *standard* whereby the quality of other milk is to be judged.

Collecting together a large number of reliable analyses of milk, we find that they furnish an average of 13·32 of total solids, and 9·44 of solids without the fat, but this latter average is doubtless much too low for milk of good quality. These data will be found to be of use hereafter in the determination of the question of the adulteration of milk. According to Wanklyn, the total solids of milk have not been known to fall below 11·8 grammes in 100 cc.

From the observation of Messrs. Müller and Eisenstuck, it appears that the milk yielded by a herd of cows remained constant in composition throughout the year. A daily analysis was made of the milk of fifteen well-fed cows, and it was found that the solids only four times during the year fell below 12 percentages, the highest percentage being 14·08, and the average 12·8 percentages.

'The milk of cows varies much according to the locality; that of cows in the neighbourhood of Paris contains from 3·6 to 3·7 per cent. of fat: of Tyrolean, Swiss and Dutch cows between 7·0 and 9·8 per cent. The composition of cow's milk in the first, third, fourth, fifth, and sixth month is pretty much the same, varying between 12·27 and 14·20 per cent. of solid matter. In the first month it contains 13·29 per cent. residue, 4·80 per cent. casein, 4·25 per cent. butter, and 3·57 per cent. lactin, and 0·66 per cent. salts. In the second month, 17·32 per cent. solid residue, 5·81 per cent. casein, 7·06 per cent. butter, 3·87 per cent. lactin, and 0·57 per cent. salts. In the eighth month 24·73 per cent. residue, 11·50 per cent. casein, 4·41 per cent. butter, 7·67 per cent. lactin, and 1·16 per cent. salts.'—Vernois and Becquerel, in 'Watts's Dictionary.'

The milk of a consumptive cow was found to contain 24·97 per cent. of solid residue, 10·13 per cent. casein and insoluble salts, 10·73 per cent. butter, 4·09 per cent. lactin and soluble salts. Wanklyn, in a sample of strippings, which is the last milk extracted from the udder of the cow at the end of the milking, found the specific gravity to be 1025, with a percentage of solids of 18·74.

The quantity of solids found in milk varies very much with its source. Thus *human* milk contains from 11 to 13 per cent. of solids; *mare's* milk about 16·2 per cent.; *ass's* milk between 9·16 and 9·53; *goat's* milk, of which *hircin* or *hircic acid* is said to be a constituent, between 13·2 and 14·5; that of the *ewe* about 14·38 per cent.; of the *sow* between 11·83 and 14·51; of the bitch from 22·48 to 27·46.

THE COMPOSITION OF CREAM.

When milk is allowed to remain at rest for some hours, a considerable proportion of the fatty matter rises to the surface, forming a layer of greater or less thickness, according to the richness of the milk, and which constitutes *cream.*

But this layer has no certain composition; the amount of fatty matter contained in it being subject to very considerable variations. In fact, cream consists of ordinary milk with its water, casein, and sugar, together with a large proportion of the fatty matter of milk. The following analyses will serve to render apparent its variable composition:—

	Analyses of Cream. Hassall.					
Water . .	62·12	61·50	63·24	49·10	43·04	45·82
Fat . . .	30·64	32·22	31·42	42·82	44·76	44·33
Casein . .	5·83	5·14	2·70	5·20	7·40	6·38
Sugar of milk .	1·27	0·74	2·36	2·46	4·45	2·92
Ash . . .	0·14	0·40	0·28	0·42	0·35	0·50

The first three creams were purchased of milkmen, while the other three were obtained direct from the dairy, and of their genuineness and quality no doubt could be entertained.

The difference in the amount of fat in the two cases is, as will be seen, very considerable, and it appears to us, that since, as in the case of milk, a standard for comparison is necessary, it would not be pressing too hard upon the vendors to insist that cream should not contain less than 35 per cent. of fatty matter.

Two samples of creamometer cream after 24 hours' standing furnished the following amounts of fat, namely 25·0 and 28·6 per cent.

The above results are important as proving that the degrees shown by the creamometer do not indicate fixed but very variable quantities of fatty matter. Thus in some cases a milk which shows only 5 degrees of cream may really be as rich as another which furnishes 7 or 8 degrees. This is certainly a strong fact in favour of making in all cases an absolute estimation of the fat of milk.

PRESERVED AND CONDENSED MILK.

There are several methods by which milk may be preserved for some time. Thus if a bottle be filled with it, the milk boiled, and the bottle then corked and sealed, it will keep for some days; but if it be heated under pressure to 121° C. the milk will be preserved, it is said, for years, although the butter may separate.

Sulphurous acid or *sulphite of soda*, *carbonate of soda* or *sugar*, all aid in the preservation of milk. Milk to which sugar and a little carbonate of soda has been added will keep for several days.

Condensed milk consists simply of milk deprived of a very considerable portion of its water, and to which cane sugar is added as a preservative material. The following analyses give the composition of some of the principal kinds of preserved milk in use in this country. Of the wholesomeness and utility of these preparations no doubt can be entertained. In some cases the water is almost entirely removed: the residue, when mixed with white sugar, may then be reduced to the state of powder, which then constitutes what is known as *milk powder*:

	Analyses of Condensed Milk. Hassall.				Milk Powder. Hassall.
Water	24·30	27·00	26·50	24·94	3·10
Casein	18·52	17·20	16·30	15·36	26·74
Milk sugar . . .	16·50	12·00	17·54	15·36	17·20
Cane sugar . . .	27·11	29·59	27·06	32·14	39·17
Fat	10·80	11·30	9·50	9·50	10·94
Mineral matter . .	2·12	2·24	2·39	2·43	2·64
Phosphoric acid . .	0·649	0·67	0·708		
	100·00	100·00	100·00	99·73	99·79

We find that in this country the average yield of one gallon of milk is about 3·2 lbs. of sugared milk: that is, it takes considerably less than three pints of milk to make 1 lb. of the sweetened condensed article. We find further that the quantity of sugar added is usually about 19 ozs. to the gallon of milk, or about 6 ozs. to 1 lb. of the sugared milk.

KOUMISS.

The sugar of milk, like other fermentable sugars, yields under the action of a ferment, as yeast, alcohol, and carbonic acid. The same change takes place when the ferment is added to the milk itself, as has been long known and practised, the resulting liquid having received the name of koumiss. This beverage has been prepared from time immemorial by the Tartars by the fermentation of mares' milk, and a somewhat similar preparation is made in Orkney and Shetland.

Sometimes the ferment is added to the entire milk, but usually a portion of the cream is abstracted and skim milk used. In other cases not only is the cream abstracted, but an additional quantity of milk sugar is added. The fatty matter is removed because it rises in the bottle, presenting a somewhat unsightly appearance, and because the beverage containing it is too rich for some persons; but the casein also is precipitated, together with the butter still remaining in the milk, and being thus rendered lighter than the serum, it likewise floats on the surface.

At the same time that a portion of the milk sugar is converted into alcohol and carbonic acid, another portion is split up into lactic acid, one molecule of the sugar furnishing, with the addition of one molecule of water, four molecules of the acid; thus $C_{12}H_{22}O_{11} + H_2O = 4C_3H_6O_3$.

The following are some analyses of koumiss recently made by us:—

Analyses of Koumiss, manufactured by Messrs. Chapman & Co.

	A No. 1, 4 days old, acidulous.	A No. 2, 30 days old, highly sparkling.	A No. 3, 30 days old, highly sparkling.	B No. 1, 4 days old, acidulous.	D No. 1, 5 days old, very sweet efferves-cing.	D No. 2, 17 days old, highly sparkling.
Lactic acid	0·416	0·684	1·152	0·542	0·373	0·614
Carbonic acid	0·361	0·819	1·228	0·389	0·468	0·754
Alcohol	0·378	0·857	1·284	0·402	0·490	0·789
Fatty matter	0·611	0·524	0·508	0·492	0·190	0·163
Sugar of milk	6·328	5·051	3·018	8·948	2·338	1·447
Casein	3·545	3·392	3·429	1·264	4·406	4·370
Mineral matter	0·370	0·342	0·392	0·654	0·680	0·672
Total solids	11·270	9·993	8·499	11·900	17·714	16·846
Glycerine	—	—	—	—	9·722	9·580

This article has been much recommended of late years in the treatment of consumption, the presence of the lactic acid being considered to aid greatly the digestion of the casein.

THE ANALYSIS OF MILK.

For most practical purposes, in order to ascertain whether a milk is genuine and of good quality, it is sufficient to take the specific gravity of the milk by the hydrometer or galactometer, and to estimate the quantity of cream by the lactometer, or as some call it, the creamometer. It is, of course, not sufficient to take either the one or the other only, but the results of both proceedings must be compared. Thus, a milk containing an excess of butter or cream will show a lighter specific gravity, and a sample with a deficiency of cream will have a higher gravity than normal milk, the gravity of which may be said to range from 1027·5 to 1034·5. But milks are occasionally met with which are either lighter or heavier, and which, therefore, exceed the above limits. The specific gravity of skim milk ranges usually from 1034·6 to 1038·6, and of the serum of milk from 1029·9 to 1031·9.

Another method of judging of the quality of milk is by estimating the total solids furnished by its evaporation, and the solids left after the removal of the fat by means of ether in the manner hereafter described. Milk of good quality should furnish, according to Henrie and Chevalier, 12·98 per cent. of total solids, and 9·85 per cent. of solids after the removal of the fat.

But supposing we desire to institute a quantitative analysis of the several constitutents of milk, the following plan may be adopted. Liquids taken for analysis are usually measured and not weighed, but it must be understood that 100 cc. of milk do not correspond to 100 grammes of milk, but to a larger quantity according to the specific gravity of the milk. Thus 100 cc. of milk having a specific gravity of 1029 would really weigh 102·9 grammes.

10 cc. of the well shaken and mixed milk are evaporated in a weighed platinum dish upon the water-bath to dryness; the residue is then weighed and re-weighed after an interval of further drying, in order to render it sure that all water has been removed. The weight when constant is noted, and indicates the percentage of *total solids* when multiplied by ten.

The dried residue is then treated, as will be presently described, with ether for the removal of the *fat*, which may be estimated from the ethereal solution; or still more simply, by re-drying the residue remaining, weighing it, and estimating the loss, which of course represents the butter. In the solids, minus the fat, we may next estimate the *sugar* and the *casein*, but for the *ash* a fresh portion of the original milk, say 5 cc., should be evaporated and incinerated.

We will now give more in detail the several processes to be followed for the estimation of the chief constituents of milk.

Estimation of total solids.—A measured quantity of milk, say 10 cc., is evaporated to dryness on the water-bath in a weighed platinum basin. The residue is repeatedly weighed until the weight becomes constant. We do not find any difficulty in effecting the complete desiccation of the solids of milk, or in the subsequent extraction of the fat, points which have been much dwelt upon by some analysts, and we have therefore not found it necessary to make use of a weighed quantity of sand or hydrated sulphate of lime, which were formerly much employed.

Estimation of fat.—The residue thus obtained is treated repeatedly with small quantities of ether, until the whole of the fat has been removed, the ether being easily separated from the residue by decantation, no filtering being required. The butter can then be estimated either from the ethereal solution, or, as explained above, by re-drying the residue and noting the loss of weight sustained. The ethereal solution is best slowly evaporated at a low temperature in a small flask.

Estimation of the sugar.—After the removal of the butter, weak alcohol is poured upon the residue and digested with it. This takes up the sugar, with a little saline matter, soluble in alcohol. By evaporating this solution and weighing the dry residue, the quantity of sugar is determined; or, as before, the residue itself may be dried and weighed, and the sugar estimated by the loss. If we wish to estimate the small quantity of inorganic saline matter, which has been taken up with the sugar, it may be done by burning the latter in the air and weighing the residue.

Or the sugar may be estimated directly from the whey by the copper solution, the details of the employment of which will be found given in the article on 'Sugar.' But the whey should be diluted with 4 or 5 volumes of water, so that the amount of sugar may be reduced to not more than 1 per cent. According to Neubauer, 100 parts of milk sugar reduce 433·1, and according to Malhaim, 415·8 parts of oxide of copper. But a more exact method is to convert the lactose into galactose, which reduces precisely the same amount of copper to the state of suboxide as do the glucoses—namely, 692·6 parts.

A very close approximation to the quantity of sugar present in milk may be obtained by simply evaporating the whey to dryness, weighing the residue, and deducting the weight of the ash left on its incineration.

Estimation of casein.—After the removal of the butter and sugar, as already described, the solids still remaining consist of casein with the greater portion of the mineral matter. This residue should now be dried, weighed, incinerated, and the weight of the ash subtracted. The difference will represent the casein.

Or other methods may be pursued. The casein may be precipitated with acetic acid, it carrying down with it nearly the whole of the butter. Wash repeatedly with weak alcohol, dry, dissolve out the fat with ether, re-dry, and weigh. The casein thus obtained contains a small quantity of mineral matter, which is to be estimated by incineration and deducted.

Or, lastly, the casein may be calculated from the amount of nitrogen, determined by the usual combustion process, the particulars of which have already been given under the head of 'Tea and its Adulteration,' but a deduction will have to be made for the albumen contained in the milk.

Estimation of albumen.—This is estimated in the serum of the milk left after the precipitation in the cold of the curd by dilute acetic acid. The acid should be nearly neutralised and the serum boiled, when the albumen will be precipitated, and may be collected and dried on a weighed filter.

THE SPECIFIC GRAVITY OF GENUINE MILK.

As the composition of milk varies, so of course does its specific gravity, but it may be said to range from 1027 to 1034. The great variation in the specific gravity of the milk is mainly occasioned by corresponding differences in the quantity of butter present; this being so much lighter than water, the greater its amount of course the less the gravity of the milk.

There are no precise or sufficient data at present existing to show to what extent the casein and the sugar of milk vary under like circumstances, and how far they affect the gravity of the milk; that is to say, there have been no sufficient number of separate determinations of those constituents of milk on which to base the limits of their variation. No doubt they do not vary to anything like the same extent as the fat, and some chemists maintain that the solids of milk, apart from the fat, represent very nearly a fixed quantity, having but a very small range of difference.

The following tables will serve to show some of the variations to which the gravity of milk is liable:—

Tables showing the variations in the Specific Gravity of Genuine Milk, and the relation of this to the percentages of Cream.

TABLE I.

	Spec. Grav. at 15·5° C.	Cream by creamometer.
	1034·5	9·0
	1029·7	7·5
	1030·4	11·0
	1031·3	9·0
	1032·1	11·0
	1027·5	20·5
	1031·2	21·0
	1028·8	12·0
	1030·3	15·3
	1032·3	18·3
	1029·9	13·2
	1030·6	13·8
Average	1030·7	13·5

TABLE II.

Cows.	Milk. Spec. Grav.	Cream.
1	1031	2°
2	1029	2½
3	1019	26
4	1008	80
5	1030	2½
6	1027	0
7	1026	13
8	1029	8
9	1030	7
10	1024	10
11	1027	10
12	1023	25
13	1024	32
14	1025	10

The preceding Table II. includes samples of both morning and afternoon milk, as well as some of the first and last milk obtained at the same milking; they are not, therefore, to be taken as average samples of milk. Moreover the gravities of the samples of Table II. were taken by means of the ordinary hydrometer, and are probably somewhat lower than they should be.

From an examination of Table II., it appears that a milk may be of high specific gravity, and yet yield but little cream (see 1); or it may be of low specific gravity, and yet afford a very large quantity of cream (see 4). It will be observed that not one of the samples in the table shows a low specific gravity with deficiency of cream.

The specific gravity of *skim milk* is of course greater and much more uniform than that of the whole milk, containing also only an insignificant amount of fat; the range of its gravity is less, usually between 1034·6 the lowest and 1038·6 the highest. In considering the question of the adulteration of milk with water, as will hereafter appear, this small range of variation will be found to be a point of great importance.

The following table shows the specific gravities of skim milk, the fat and the total solids contained in it, the gravities having been taken by means of the specific gravity bottle.

Spec. Grav. of Skim Milk at 15·5°C.	Fat in Skim Milk.	Total Solids of Skim Milk.
1038·6	0·	11·26
1034·6	0·14	10·16
1036·9	0·24	11·04
1036·2	0·10	10·28
1037·4	0·08	10·72
1035·8	0·20	10·36
1036·0	0·06	—
1037·1	0·11	—
1036·3	0·10	—
1038·4	0·10	11·56
1036·9	0·06	11·05
1037·0	0·04	10·58
1035·4	0·28	11·10
1035·3	0·12	9·90
1035·4	0·08	9·88
Average 1036·35	0·11	10·57

The specific gravity of the *serum* of milk is due mainly to the sugar contained in it; and as this constituent is said to be the least variable, so is the specific gravity of the serum the least subject to variation—a circumstance of considerable importance, as will be shown presently.

Tables showing the Density of Serum, and its relation to the Specific Gravity of Milk.

TABLE III.

Cows.	Spec. Grav. of Milk.	Spec. Grav. of Serum.
1	1028·9	1031·8
2	1030·3	1031·4
3	1032·3	1030·2
4	1029·9	1031·9
5	1030·6	1029·9

TABLE IV.

Cows.	Milk. Spec. Grav.	Serum. Spec. Grav.	Cows.	Milk. Spec. Grav.	Serum. Spec. Grav.
1	1029	1028	22	1022	1027
2	1026	1028	23	1030	1027
3	1029	1025	24	1031	1028
4	1031	1027	25	1028	1028
5	1030	1027	26	1030	1028
6	1008	1025	27	1031	1028
7	1019	1027	28	1028	1027
8	1026	1026	29	1028	1027
9	1030	1027	30	1027	1028
10	1028	1028	31	1028	1027
11	1027	1027	32	1030	1028
12	1026	1027	33	1029	1028
13	1027	1025	34	1026	1027
14	1029	1027	35	1024	1026
15	1030	1027	36	1027	1026
16	1030	1027	37	1026	1028
17	1023	1028	38	1028	1028
18	1023	1028	39	1026	1027
19	1025	1027	40	1026	1026
20	1024	1027	41	1030	1026
21	1024	1028	42	1023	1028

Table IV. includes many samples of milk of an exceptional character. The gravities, it should be noted, given in this table were ascertained by means of an ordinary hydrometer.

While the specific gravity of milk extends over a wide range, varying from 1008 to 1034, that of the serum, on the contrary, is subject to only a slight variation, the limits of this in Table III. lying between 1029·9 and 1031·9, and in Table IV. between 1025 and 1028.

We have here, then, one more fixed datum from which to determine the adulteration of milk with water, a point of the greatest importance.

The specific gravity of *skim milk*, although not so fixed as that of the serum, is yet much more so than that of whole milk: its average weight is estimated by Pereira at 1034·8, but we find it to range between 1034·6 and 1038·6, the average being 1036·3. (See table, p. 401.)

VARIATIONS IN THE COMPOSITION OF MILK.

It has been stated that the composition of milk is subject to very great variation according to several modifying circumstances. The chief of these are—the age of the cow, its condition, the time and frequency of milking, the nature of the food, housing of the cows, and temperature. We shall bestow a few remarks on each of these causes of variation.

Influence of age on milk.—With respect to age, a young cow with her first calf gives less milk than with her second, third, or fourth calf, she being considered to be in her best condition, in most cases, when from four to seven years old.

The period during which cows give milk after calving is usually five or six months, but very frequently the time is much prolonged beyond this; we have been informed of an instance of a cow continuing to give milk for three years and a half after calving.

Influence of condition on milk.—The first milk yielded by the cow after calving is yellow, thick, and stringy: it is called *colostrum*, and by milkmen and others, 'beastings.' This state of the milk lasts from about three weeks to a month, but is very bad for the first ten days, during which time the milk is not fit for use. From the end of the first to the termination of the third or fourth month the milk is in its best condition.

The cow carries her calf for forty weeks, or ten lunar months. It is the common practice to milk the cow regularly for the first seven, eight, or nine months of this period, a practice which, at first sight, appears to be highly objectionable, but which is really not so much so as might be supposed; and it is rendered absolutely necessary by the fact that cows could not otherwise be profitably kept; nevertheless, it is very important that the milking should not be continued too long, for the sake of the cow, the calf, and the milk itself: in general it should cease at the end of the seventh month; many cow-keepers, however, continue to milk up to a very short period of calving.

Another very objectionable practice is to permit the cow again to become in calf within two or three months after having calved; the object of doing so is to derive as much profit as practicable from the animal, without regard to the effect on its constitution, the quality of the milk, or the growth of the calf. It is impossible to conceive that a cow can continue to yield large quantities of good milk daily, and afford, at the same time, sufficient nourishment for carrying on effectively the process of gestation.

Influence of food on milk.—The natural food of the cow is evidently that derived from pastures, viz. grass, the milk obtained from cows fed upon this being of excellent quality and sufficiently rich for all purposes.

The next most natural food is dried grass or hay, which is given largely to cows in winter, the milk being nearly the same in quality as from grass.

Beet-root, carrots, mangold-wurzel and oilcake being very nutritious, are also usually given to cows in the winter time with advantage. With regard to the effect of beet-root and carrots on milk, we obtain the following information by MM. O. Henrie and Chevalier.

	Normal Milk.	Fed on Beet.	Fed on Carrots.
Casein (cheesy matter)	4·48	3·75	4·20
Butter . . .	3·13	2·75	3·08
Sugar of milk . .	4·77	5·95	5·30
Salts, various . .	0·60	0·68	0·75
Water . . .	87·02	86·87	86·67
	100·00	100·00	100·00

It will be observed that, according to the above tables, the effect of feeding cows on carrots is to occasion a slight diminution in the amount of casein and butter, but an increase in the quantity of sugar, while feeding them on beet-root, reduces still more the quantity of casein and butter, but very largely increases the sugar—effects which, from the richness of carrot and beet in sugar, might have been anticipated.

As is well known, a very considerable number of the cows which supply London with milk are kept in various confined and unhealthy places in the metropolis; such cows are seldom turned out to grass; the system of feeding adopted being altogether artificial and unnatural, brewers' grains and distillers' wash forming much of their food; these stimulate the animals unnaturally, and under the stimulus large quantities of milk of inferior quality are secreted, the cow quickly becoming worn out and diseased in consequence.

In reference to the effects of grains on cows, Mr. Harley makes the following remarks:—

'Brewers' and distillers' grains, and distillers' wash make the cattle grain-sick, as it is termed, and prove injurious to the stomach of the animal. It has been ascertained that if cows are fed upon these grains, &c., their constitutions become quickly destroyed.'

Influence of temperature on milk.—In hot countries and dry seasons the quantity of milk yielded is said to be less, but the quality is richer; it is also stated that cold favours the production of sugar and cheese, whilst hot weather augments the amount of butter.

It would be extremely desirable to ascertain precisely the extent to which the quality of milk is influenced by weather.

Influence of the time and frequency of milking.—With regard to the quality of milk as affected by the time and frequency of milking, morning milk is said to be better than that obtained in the afternoon; and the milk of cows when milked but once a day is richer than either. It is the common belief that the last portion of the milk obtained at any milking is richer than the first. Many years since we took pains to ascertain whether there is any foundation for such an opinion, and find it to be really the case to a remarkable extent, as will appear from the following table.

Table showing the Difference in the Quality of the First and Last Milk obtained at each Milking.

Cows.	Milk. Spec. Grav.	Cream.
	First Milk. Afternoon.	
1	1027	9°
2	1026	13
3	1027	8
4	1029	7
5	1030	11
6	1030	8
7	1029	3½
8	1031	2
		61½
	Last Milk.	
1	1023	25
2	1023	22
3	1025	10
4	1024	15
5	1024	32
6	1022	25
7	1026	7½
8	1030	5
		141½

From an examination of these tables it appears that the last milks are of much lower specific gravity than the first; and hence, had the specific-gravity test alone been relied on, they would have been pronounced to be inferior in richness to the first; a conclusion the reverse of that which is correct. Thus, while the cream of the whole eight samples of the first milks amounted to 61½ percentages, that of the last amounted to 141½; that is, they contained more than double the quantity of cream. This fact is not without practical importance.

It is a common practice for invalids and others to procure their glass of milk direct from the cow: we thus perceive that in this way they seldom obtain the proper proportion of butter, a circumstance which may be of advantage in some cases, and of disadvantage in others. In London it is now common for cows to be driven through the streets, and to be milked in the presence of the purchasers: although in this way the buyer succeeds in procuring it genuine, he does not always obtain the best milk.

The great difference in the amount of cream contained in the first and last milk taken from the cow at one milking, appears to be satisfactorily explained on the supposition that the fatty matter of the milk obeys the same laws of gravity in the udder of the cow that it does when set aside in an open vessel.

The following tables show the variations in the specific gravity of milk, and the percentages of cream in morning and afternoon milk.

Table showing the Specific Gravity of Pure Milk, and the Percentages of Cream.

Morning Milk.

Cows.	Milk. Spec. Gravity.		Cream.
Richmond.			
1	1030		6½
2	1031		7
3	1028		4½
4	1030		9
5	1031		10
6	1028		7½
London.			
7	1030		12
8	1023		5
9	1029		7
10	1028		9
Average nearly	1029	Total	77½
		Average about	7½

Afternoon Milk.

Cows.	Milk. Spec Gravity.		Cream.
Richmond.			
1	1028		7½
2	1027		10
3	1027		6
4	1028		9
5	1028		11½
6	1027		7½
London.			
7	1028		22
8	1026		6
9	1026		6
10	1026		11
Average about	1027	Total	96½
		Average more than	9½

The Richmond cows from which the first six morning and afternoon milks were obtained, were fed partly on grass and partly on grains.

The samples were taken from the milk-pail containing the whole of the milk obtained from each cow, and whilst still warm.

From the preceding tables (p. 406) it appears:—

That the *specific gravity* of genuine milk, in its ordinary condition, varies between 1026 and 1031; and that the average specific gravity of the morning milk is about 1029, and the afternoon 1027; but the results of more recent observations gave a variation of from 1029 to 1034 for genuine milk. (See table, p. 400.)

THE HOUSING OF COWS.

In a very useful little pamphlet, published some years since by Mr. H. Rugg, surgeon, on London milk, we meet with many particulars relating to the improper mode pursued in feeding and housing cows kept in various parts of the metropolis.

'Any place, any hovel,' writes Mr. Rugg, 'cow-keepers seem to consider will do for a cow—narrow lanes, confined corners, &c.—and yet they wonder how it is that they lose so many from disease. Can any one with a grain of common sense at all wonder that cows should be afflicted with disease when they are huddled together in a space that does not allow them sufficient breathing-room, with their heads placed close up to the wall, and without a sufficient current of air or ventilation? The carbonic acid expired from their lungs is, before it can rise, the greater part inhaled again, unmixed with a sufficiency of pure air, so necessary for the oxidation of the blood, and consequent vitality of the body.'

Other observations on the same subject will be found recorded in the 'Harleian Dairy System,' p. 14; 'Aiton's Dairy Husbandry,' p. 70, and in a pamphlet on 'The Sanitary Condition of the Parish of St. James's, Westminster,' by the Hon. F. Byng.

The necessity for an abundance of pure air is shown by the following calculation:—Dr. Thomson states that one cow, consuming 6 lbs. of carbon in its daily food, for respiratory purposes would require 956¼ cubic feet of atmospheric air.

THE CHARACTERISTICS OF GOOD MILK.

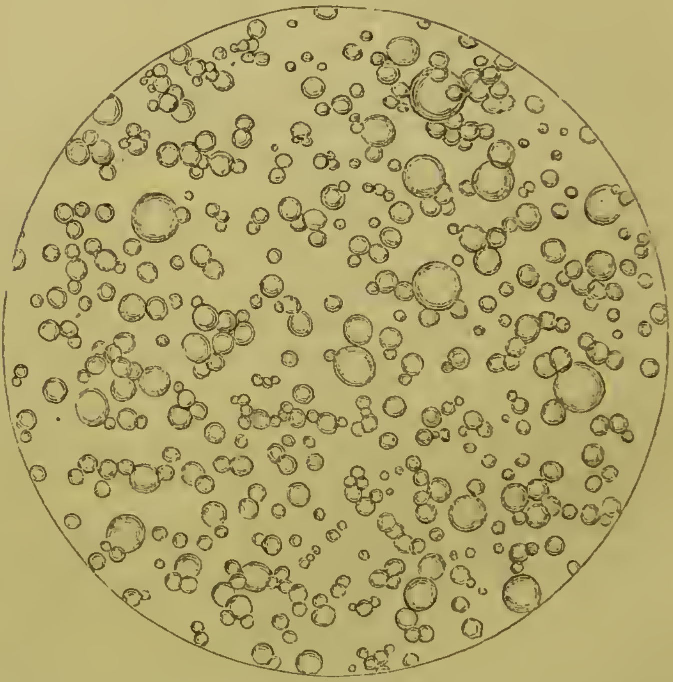
Good milk is a white homogeneous fluid, of sweet and bland taste, not becoming viscid on the addition of ammonia. It should furnish a mean of total solids of about 13·17 per cent. and at the least 9·44 of solids not fat, and should yield an average of about 11½ percentages, by the lactometer, of cream.

The specific gravity of genuine whole milk is liable to vary, ordinarily, however, within the limits of 1029 and 1034, the amount of cream varying in a corresponding ratio; the gravity of the skim milk ranging from 1034·6 to 1038·6.

Examined with the microscope, milk is found to contain myriads of beautifully formed globules of fatty matter of various size, and reflecting the light strongly, and which globules are entirely and readily soluble in caustic potash; in fact, good milk under the microscope presents the appearance shown in fig. 124.

Fig. 124.

Good Milk.



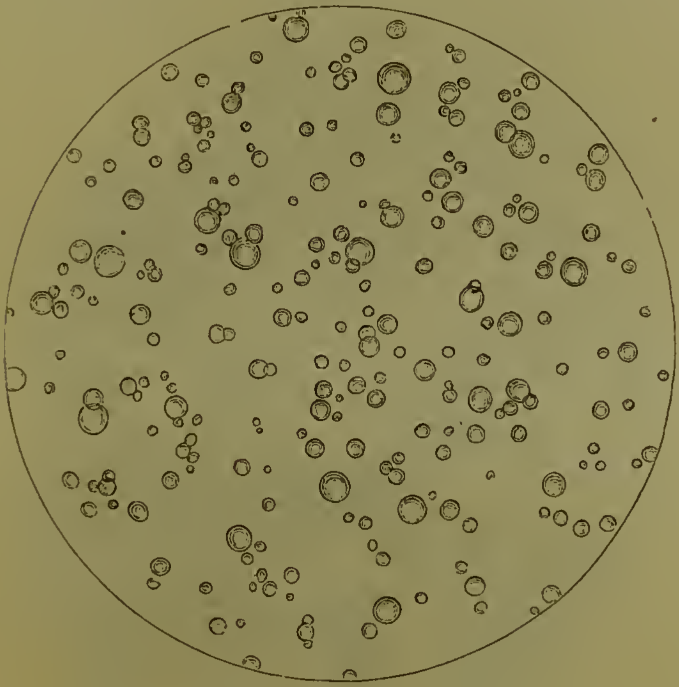
This and the four following figures are all drawn to a scale of about 630 diameters.

These globules do not consist entirely of fat, but are coated with an envelope formed of some albuminous substance, as shown in the following paragraph:—

'Henle first proved the existence of an external envelope: he added acetic acid to the milk, and found that the shapes of the globules were thereby distorted. Mitscherlich found that the globules were not dissolved when milk was shaken up with ether, which would have been the case if they were a simple emulsion of fat; if, however, caustic potash or carbonate of potassium, which dissolves the envelope, was previously added, the fat was then dissolved by ether. Lehmann also remarked that the surface of the globules in milk merely treated with ether appeared less transparent, turbid, and wrinkled, as if it had been coagulated. The ether took up the fat on the addition of phosphate of sodium. Moleschott acted on the coagulum obtained by adding alcohol to milk with acetic acid, and extracted the fat with ether; there remained many unbroken fat envelopes in the form of little vesicles, which he was able to fill with an ethereal solution of chlorophyll; they contained no fat. From this he not only proved the existence of the fat envelopes, but concluded also that they are organised.'—Long, in *Watts's Dictionary*.

Fig. 125.

Poor Milk.



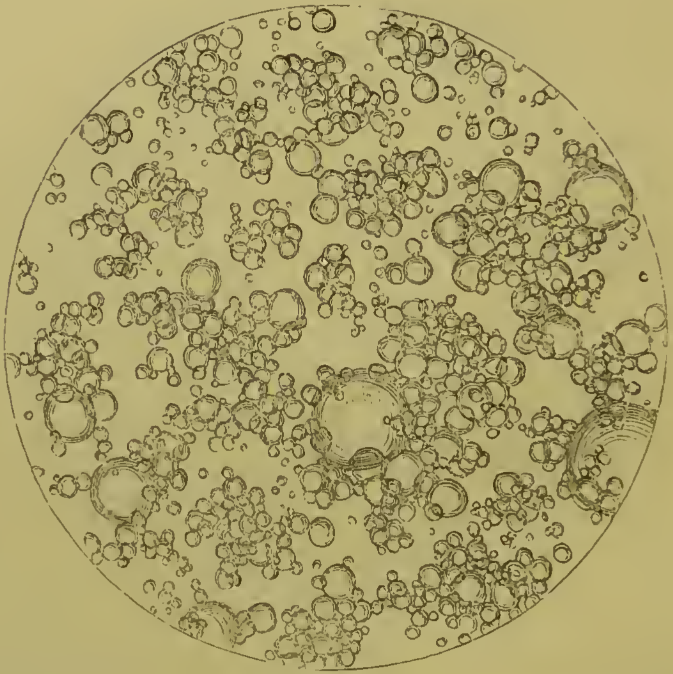
If the milk exhibit any want of complete homogeneousness or is of imperfect liquidity; if it be viscid, or become so on the addition of ammonia; if, examined with the microscope, blood, pus, or colostrum corpuscles are present, the milk is not healthy milk of good quality; lastly, if the fat globules are comparatively few and of small size, the milk is poor.

'Professor Mosler has directed attention to the poisonous effects of "blue milk," that is to say, milk covered with a layer of blue substance, which is in fact a fungus, either *Oidium lactis* or *penicillium*, which seems to have the power, in certain conditions, of causing the appearance in the milk of an aniline substance. The existence of this form of fungus was noted by Fuchs as long ago as 1861. Milk of this kind gives rise to gastric irritation (first noted by Steinhof); and in four cases, noted by Mosler, it produced severe febrile gastritis.

'Milk which is not blue, but which contains large quantities of oidium, appears, from Hessling's observations, to produce many dyspeptic symptoms, and even cholera-like attacks, as well as possibly to give rise to some aphthous affections of the mouth in children.'—*Parkes' Hygiene.*

Fig. 126.

Cream.



Cream consists for the most of the fat globules, some of which are of very considerable size (fig. 126).

The curd of milk, as already explained, is composed of both the cheese and the fat globules. Its appearance under the microscope is represented in fig. 127; the casein or cheese is distinguished by its granular texture.

Colostrum.—The first milk yielded by the cow after calving, called *colostrum*, is characterised, as before noticed, by the presence of numerous corpuscles of large size and granular appearance. Cow's milk in the state of colostrum is represented in fig. 128.

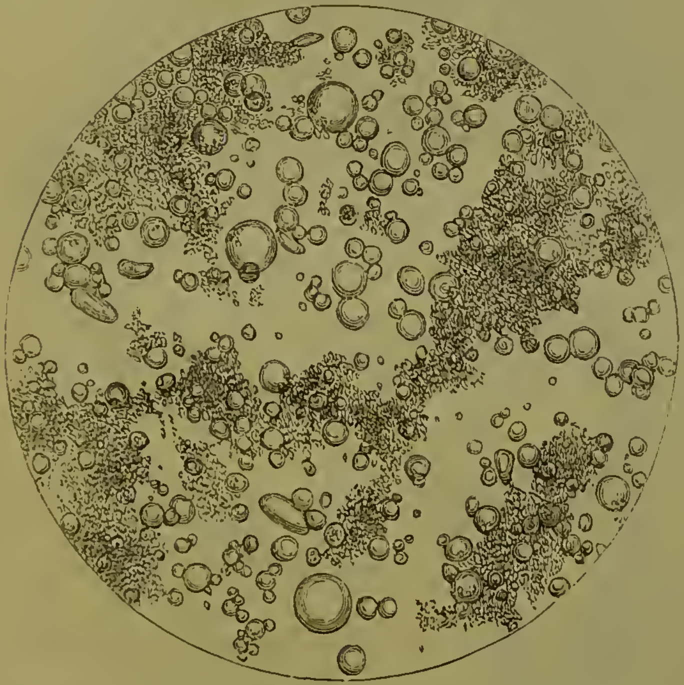
The colostrum corpuscles are destroyed by potash or by acetic acid. Iodine turns them of a yellow colour, and hence it is inferred that they contain a large amount of an albuminous substance.

The Apparatus employed to Determine the Purity and Quality of Milk.

Independent of a quantitative chemical analysis, the purity and quality of milk are often judged of by its specific gravity and the quantity of fatty matter or cream which the milk furnishes.

Fig. 127.

Curd of Milk.



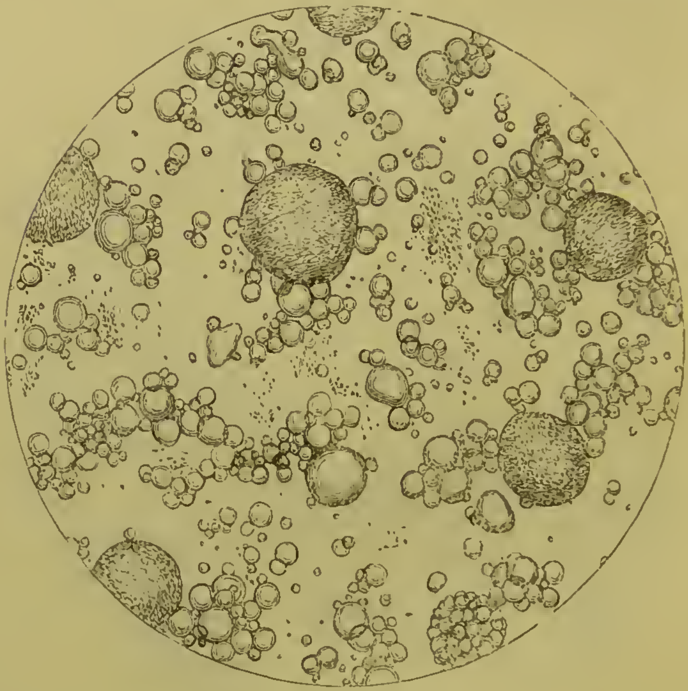
The *specific gravity* of milk is best determined by the ordinary specific gravity bottle; but it is more frequently ascertained by means of the common hydrometer, or by the galactometer, of which several varieties have been devised.

The best of the galactometers is the instrument invented by M. Dinocourt, named the *Centesimal Galactometer* (fig. 130).

Pure milk not deprived of its cream has a less specific density than skim milk, caused by the lightness of the cream. If the cream be either in part or wholly removed from milk, the residual milk will weigh heavier than that which contains its normal proportion of cream. Skim milk, therefore, tried by the galactometer scale, for pure milk only, would give a higher specific gravity than ordinarily belongs to pure milk, and hence the error might be committed of supposing it to be pure, an error which can be corrected by means of the creamometer, whereby the percentage of cream is estimated; should this percentage fall short of that which is proper to pure milk, the sample of milk is one the value of which should be determined by the scale for pure skim milk.

Fig. 128.

COLOSTRUM.

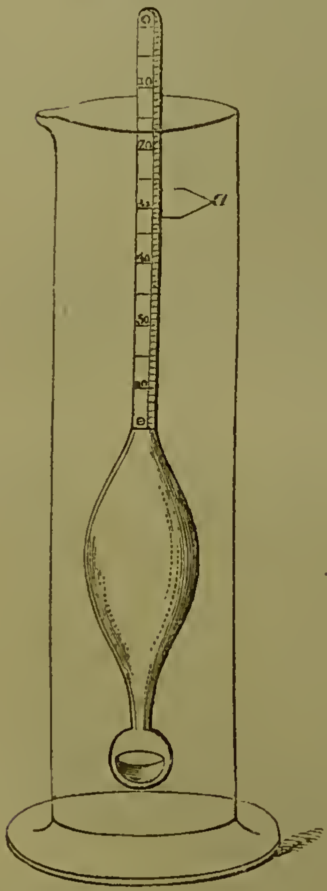


Again, if to such skim milk we add a certain percentage of water, we restore to it its proper specific gravity, and therefore this milk would show, with the centesimal galactometer, the density proper to pure milk, and hence this fraud would escape detection. In order to meet cases of this kind, which are of frequent occurrence—namely, the complete or partial removal of the cream, it is necessary also to employ the creamometer, and ascertain by it whether the sample under examination contains the proper proportion of cream or not; indeed, it is not possible to come to any certain or safe conclusions without employing the two instruments, the lactometer or hydrometer, for

Fig. 129.

COMMON HYDROMETER.

(*Reduced one-half.*)

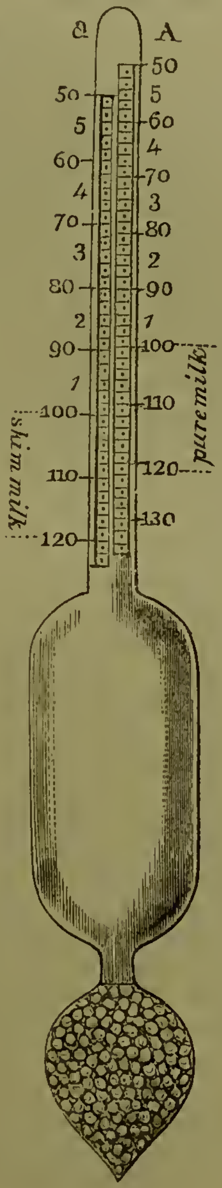


a, Range of pure milk.

Fig. 130.

THE CENTESIMAL GALACTOMETER.

(*On a reduced scale.*)



taking the specific gravity of the whole milk, and the creamometer, to measure the cream.

Where the specific gravity of a milk is very low, and this not produced by a large excess of cream, it is due to the admixture of water, the quantity of which may be determined with considerable accuracy from the milk, or, better still, from the skim milk or whey, by the common hydrometer.

The reason why the centesimal galactometer has been provided with two scales, one for pure and the other for skim milk, is, of course, on account of the very different densities possessed by each.

The great advantage of the centesimal galactometer consists in its centesimal graduation, whereby calculation is so much facilitated.

It is proper, in using either the specific gravity bottle or the ordinary hydrometer, to take the specific gravity of milk always at the same temperature, namely 60° F = 15·5° C. This precaution is especially necessary with the centesimal galactometer, in which, from the delicacy of the graduation, a comparatively slight alteration of temperature occasions a difference of several degrees.

When it is desired to make use of the scale for skim milk, one portion of the milk is to be set aside for about twenty hours in a creamometer; another in a pan for the same length of time; the percentage of cream in the creamometer is to be noted, and the density of the milk in the pan, after being skimmed, taken in the ordinary manner with the centesimal galactometer, or, still better, with the specific gravity bottle.

Of all the constituents of milk, the sugar is the least subject to variation, and as the density of the serum of milk is principally due to the sugar, its specific gravity of course is also but little liable to alteration. This statement is founded upon the results of numerous observations. It therefore long since occurred to us that the utility of the galactometer might be greatly enhanced by the addition of a centesimal scale for the serum of milk. The advantage of this scale would be that—starting from a fixed point, the normal specific gravity of the serum—it would show, with considerable nicety, the extent of the more usual adulteration of milk—namely, that with water: for in proportion as water is added, so does the weight of the serum diminish, and this in such a marked manner that the quantity of water added may readily be determined in percentages. Numerous observations are first required, in order to fix accurately the normal specific gravity of the serum of the milk of the cow.

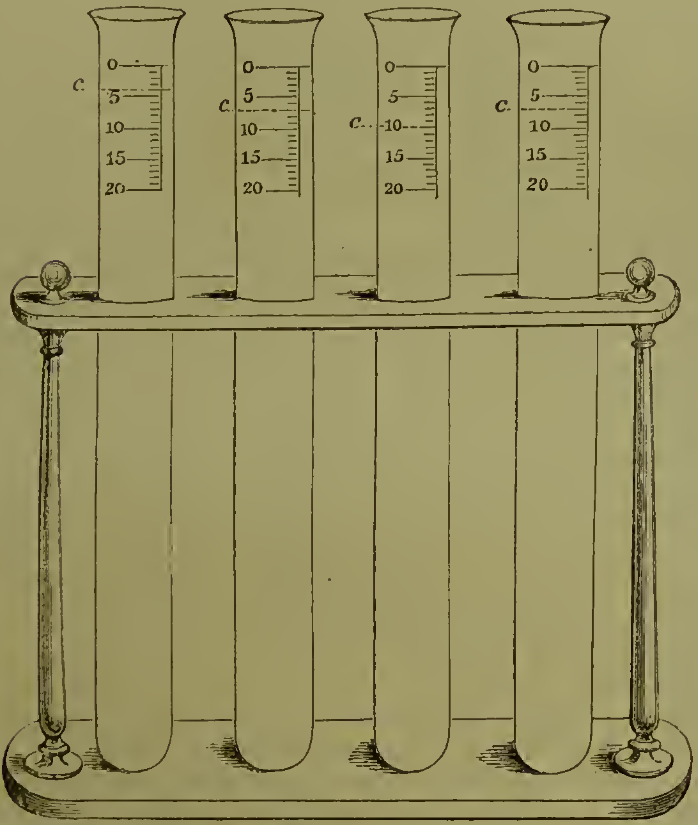
Method of determining the cream.—The amount of cream is determined by means of an instrument invented by the late Sir Joseph Banks, termed a *creamometer*. This consists of a tube, usually eleven inches long and half an inch in diameter; the upper inch or two inches of this are graduated in tenths of an inch—that is, in hundredths of the whole. The tube is filled with milk, and set aside for twenty hours; the cream ascends to the surface, and its amount is determined by the thickness of the stratum formed, and which is ascertained by noting the number of degrees or tenths through which it extends.

As the quantity of cream not unfrequently exceeds twenty, and has even been known to reach eighty per cent., the tubes should in all cases be graduated for nearly their whole length.

Fig. 131.

Creamometer and Stand.

(*On a reduced scale.*)



The dotted lines indicate the percentages of cream on four samples of milk from different cows after standing twelve hours.

The construction of the creamometer is shown in the accompanying woodcut, representing a rack, holding four of these instruments (fig. 131).

Cream forms more quickly in warm than cold weather; and in making comparative observations on a number of samples, it is proper that they should be set aside in creamometers at the same time and for the same period; the degrees should not be read off until the full period of twenty hours has elapsed.

The thickness of the stratum of cream formed on genuine milk is, like the specific gravity, subject to considerable variation: in two extreme cases we have met with, one of the samples showed but *two* degrees of cream, and the other *eighty*. According to Dr. Normandy, the thickness of the stratum of cream on pure milk is generally from 8 to 8½ percentages; M. Dinocourt finds the percentages to range between 9 and 14, while, according to our numerous observations, the *average* is 11½ percentages; but it is important to remember that the cream which collects on the creamometer has not in all cases an identical composition, but that the amount of fat contained in it is subject, as has already been shown, to very considerable variation.

It must not be forgotten that London milk, as delivered to houses, consists in general of the milk of different cows mixed together; and therefore, in order to determine what ought to be the depth of cream formed on good milk, we should take the average amount obtained from such mixed milks.

We have said that the quantity of cream varies much in different samples of genuine milk; and not only is this the case, but it should also be known that the amount of cream yielded by any sample of milk is no certain criterion by which to judge of its quality, as some milks are rich in cream and yet may be watered and so be deficient in casein and sugar.

It has been stated that the addition of a small quantity of warm water to milk increases the amount of cream; the belief in the accuracy of this statement is general, and it is commonly acted upon by milkmen; nevertheless, the assertion is entirely erroneous—the addition of water to milk does not increase the quantity of cream; it merely facilitates and hastens, in a most remarkable manner, its formation and separation, as is shown by what follows:—

Six creamometers were filled, one with pure milk, the remainder with the same milk diluted respectively with ten, twenty, thirty, forty, and fifty per cent. of water.

Twenty minutes after the addition of the water, the creamometer showed, in the milk containing fifty per cent. of water, six degrees of cream; in that with forty per cent., five degrees; with thirty per cent., four degrees; with twenty per cent., three degrees; with ten per cent., one degree; and in the pure milk, half a degree only.

At the end of forty minutes, the cream stood thus: six and a half degrees on the milk containing fifty per cent. of water; six on that with forty per cent.; five and a half on that with thirty per cent.; five on that with twenty per cent.; four and a half on that with ten per cent.; and four on the pure milk.

At the end of twelve hours, the milk with fifty per cent. of water showed five degrees of cream; that with forty per cent., five degrees and three-quarters; that with thirty per cent., six and a half degrees;

that with twenty per cent., seven degrees and a quarter; that with ten per cent., eight degrees; and the pure milk, nine degrees of cream.

It thus appears that the addition of a large quantity of water to milk occasions an almost immediate formation of cream; of this fact, in some cases, it would be an advantage to dairymen to avail themselves, but it does not augment the amount.

Some persons form their judgment of the quality of milk simply by its density, regarding all samples which do not indicate a certain specific gravity as of inferior quality. We have already seen that this method is very fallacious, and that by it some milks, rich in cream, would be pronounced of inferior quality, in consequence of their low density; while others, deficient in that constituent, would be declared of superior quality on account of their high density.

Others rely upon the indications afforded by the creamometer, which also has its fallacies, but which are not so great when the instrument is used with the necessary precautions, as those relating to the specific gravity of milk. The creamometer has regard to only one component of milk, namely, the fatty matter.

The following facts will show how misleading is the creamometer in some cases. We have met with several samples of *genuine* milk, which gave only three or four percentages of cream, but which yet possessed a specific gravity of 1030; judged by the creamometer test alone, such milks would be pronounced by all to be very poor, and by some even to be adulterated. Now this conclusion would be to a very great extent erroneous; for such milks, although certainly deficient in butter, have the full proportion of the remaining constituents, namely, the cheese and the sugar. Again, we constantly meet with samples of milk giving six, eight, or more percentages of cream, and which nevertheless, as shown by the specific gravity of the skim milk, are unquestionably adulterated with large quantities of water.

The observer who relied upon the indications of the creamometer would have regarded these last samples as of average quality. The enquirer, therefore, should not rely solely upon either the specific gravity or the creamometer tests, but in all cases employ both, the one acting as a corrective of the fallacies of the other, or he may determine the amount of solids not fat, basing upon it his calculation for water.

For all practical purposes, the above methods of examination are sufficient. Should it be desired to institute a quantitative analysis, we may then adopt the processes already given under the head of the analysis of milk.

Donné's lactoscope.—Some years since an instrument, termed a lactoscope, was invented by M. Donné, of Paris, for determining the richness of milk by estimating the relative opacity of thin stratums of milk, and which opacity is mainly dependent upon the number of fat globules therein contained.

An instrument similar in principle but differing considerably in its details, the light of a candle being employed instead of daylight, has been devised by Vogel. Both instruments are no doubt capable of furnishing approximate results as regards the amounts of fatty matter present, but their use, having so many other ready and certain means of ascertaining the fact of the adulteration of milk at our command, need not be here recommended.

THE ADULTERATIONS OF MILK.

There are few articles of food more liable to adulteration, and this of the grossest description, than milk. The most prevalent and important adulteration is that with *water*. Now some few persons who have not reflected closely upon the matter, may be disposed to make light of the adulteration of milk with water, and to speak in rather facetious terms of the cow with the iron tail; but it is surely no light matter to rob an important article of daily consumption, like milk, of a large portion of its nutritious constituents.

But the adulteration with water is not the only adulteration to which milk is liable; the large addition of water frequently made to it so alters its appearance as to cause it to assume the sky-blue colour so familiar to us in our schoolboy days, and so reduces its flavour, that it becomes necessary to have recourse to other adulterating ingredients, namely, *treacle* or *sugar*, to sweeten it; *salt*, to bring out the flavour; and *annatto*, about which we shall have much to say hereafter, to colour it.

Further, there is no question but that *chalk*, *starch*, and even *cerebral matter*, have been and are occasionally, though rarely, employed in the adulteration of milk, although it has not happened to ourselves to meet with these substances.

Starch and cerebral matter have been met with at different times by more than one observer. The late Professor Queckett used formerly to exhibit drawings made by himself, from samples of adulterated milk, showing the presence of both starch and cerebral matter.

With regard to the use of chalk, a manufacturer of preserved milk recently informed us that it sometimes happened to him to find carbonate of lime or chalk at the bottom of the dishes or pans on the evaporation of large quantities of London milk.

There is also good reason for believing that *turmeric* as well as annatto are sometimes used to colour milk and cream. Mr. Gay states that milk is sometimes adulterated with decoction of boiled *white carrots*.

Further, it has been stated that *gum*, *dextrin*, and *emulsion of hemp seed* have been employed; the use of the latter article is but little probable.

A practice frequently resorted to, although it is not ordinarily regarded as an adulteration, should here be mentioned; a part or even the entire of the cream is removed, and the *skimmed milk*, mixed with some fresh milk, subsequently sold as whole milk.

Owing to the storage of milk in vessels of *lead, copper* and *zinc,* it is often contaminated with those metals, especially with the last named.

An ingenious writer, whose name we do not at the present moment remember, has considered the subject of the supply of London with milk statistically, and he has arrived at the conclusion that the number of cows supplying London is not more than sufficient to provide each person with about a tablespoonful of milk per day. If this statement is correct, some idea may be formed of the extent to which water is made to do duty for milk.

Results of the Examination of Samples of Milk.

The results of the examination of twenty-six samples of London milk, made some time since, were—

That *twelve were genuine,* but of these two showed a deficiency of cream.

That *fourteen were adulterated,* the adulteration consisting principally in the addition of *water,* the percentages of which ranged from 10 to 50 per cent., or one-half water.

The specific gravities of the *milks* varied from 1015 to 1030, of the *serums* from 1016 to 1028, the cream furnished ranged from 2 to 29 percentages, the average being nearly 10 percentages.

The results of the analysis of fifteen samples of milk purchased in the metropolis, in 1871, were:—

Name.	Specific gravity.	Gravity of Serum.	Case-in.	Fat or butter	Cream.	Milk sugar.	Ash.	Water added.	Total solids.
Standard sample	1030	—	4·48	3·13	8·5	4·77	0·60	none	12·98
1 Aylesbury Dairy Compy. (lim.) .	1032	1029·5	4·14	3·50	10·0	4·95	0·74	—	13·36
2 Express Country Dairy Compy.	1030	1028	3·41	3·10	8·5	5·20	0·69	—	12·40
3 Sainsbury . .	1032	1030	4·25	3·04	6·0	5·41	0·75	—	13·45
4 Milk store . .	1029	—	3·34	2·10	4·5	2·35	0·56	33	8·35
5 ,, . .	1028	—	4·20	2·30	5·0	2·90	0·80	25	10·20
6 ,, . .	1029	—	1·60	3·30	11·0	3·69	0·43	30	9·02
7 ,, . .	1028·5	—	4·30	3·50	10·0	2·45	0·65	21	10·90
8 ,, . .	1028	1027·1	3·93	2·76	7·5	3·49	0·72	13	10·90
9 ,, . .	1226	—	3·50	2·00	4·0	3·90	0·50	16	9·90
10 ,, . .	1225	—	3·20	2·00	Curdled	2·80	0·60	30	8·60
11 ,, . .	1025	1022	2·06	2·11	4·50	4·09	0·60	28	8·86
12 ,, . .	1023·2	1020·8	2·12	2·33	6·25	3·99	0·56	29	9·00
13 ,, . .	1022	1020·1	3·19	2·00	4·5	2·74	0·57	31	8·50
14 ,, . .	1019·4	—	3·00	2·00	4·0	2·50	0·40	37	7·90
15 Shop in Clapham	1012·6	1011·6	1·15	1·05	2·50	2·26	0·30	61	4·76

Samples 4, 5, 6, 7, 9, 10, and 14 were likewise tested for *cane sugar.* Nos. 9 and 10 were free from it, while in 4, 5, 6, 7, and 14, the quantities found were respectively 1·35, 0·70, 1·68, 1·35, 0·85. These results show that the adulteration of London milk with *sugar* or *treacle* is not uncommonly practised.

THE ADULTERATIONS OF CREAM.

As was the case with milk, so with cream. One of its principal adulterations is with water, or rather we should say with skim-milk. Of course this adulteration is very easily practised, the milkman having nothing further to do than to remove, together with the cream itself, a portion of the underlying skim-milk.

Another adulteration is with *casein*. Supposing the milk to have turned somewhat sour, a portion of the curd from the fat contained in it would readily rise to the surface and be skimmed off with the cream, or the curd itself may be purposely introduced.

Other adulterations which are stated to be practised are with *sugar*, *gum*, *gum tragacanth*, *starch*, *soda*, and *carbonate of magnesia*, but of these adulterations we do not ourselves possess any independent knowledge.

THE DETECTION OF THE ADULTERATIONS OF MILK.

The articles employed in the adulteration of milk and cream, the methods for the discovery of which we have now to describe, are *water*, *sugar*, including *treacle*; *salt*, *annatto*, *turmeric*, *gum tragacanth*, *starch*, *cerebral matter*, *chalk*, *soda*, and *carbonate of magnesia*.

Certain alleged adulterations of milk, either not likely to be practised, or but rarely resorted to, it is not necessary to notice.

There are two general methods by which the fact of the adulteration of milk may be determined; the one indirect, as by a quantitative analysis of the milk for its more important constituents, and by the deficiency of one or more of which the existence of adulteration may be inferred; the other direct, as by detection, either through chemistry or the microscope, of the adulterating substance or substances.

In some cases these two methods may be combined.

The methods by which the normal constituents of milk may be determined quantitatively have already been described.

On the detection of water.—Milk being much heavier than water, when that liquid is added to it the specific gravity of the mixed article is less than that of genuine milk, and the diminution, within certain limits, is proportionate to the quantity of water added. In the knowledge of these facts, we are furnished with methods whereby the adulteration of milk with water may be determined quantitatively.

This may be done by taking the specific gravity of either the entire milk, skimmed milk, or serum.

But since the specific gravity of even genuine milk is subject to wide ranges, owing mainly to the variable quantities of fatty matter present, it is in all cases better to take the specific gravity of either the *skim milk* or the *serum*.

A table has already been given (p. 401) of the specific gravity of skim milk, which was found to range from 1034·6 to 1038·6, the average being 1036·3.

In the following table the specific gravity of skim milk is given, containing exactly 9·4 per cent. of solids not fat, this being the amount below which genuine milk of even the poorest quality rarely if ever falls; and also the gravities of the same milk adulterated with various proportions of water.

Tables showing the Adulteration of Milk with Water, based upon the Gravity of the Skim Milk.

TABLE I.

Per cent. of Water.	Specific Gravity.	Difference.	Total Solids.
0	1030·48	—	9·40
5	1028·84	1·64	8·93
10	1027·36	1·48	8·46
15	1025·72	1·64	7·99
20	1024·12	1·50	7·52
25	1022·56	1·56	7·05
30	1021·04	1·52	6·58
35	1019·52	1·52	6·11
40	1018·04	1·48	5·64
45	1016·40	1·64	5·17
50	1014·48	1·92	4·70
55	1013·08	1·60	4·23
60	1011·68	1·40	3·76

5% of water = 0·47 solids not fat = 0·0235 gram. if 5 cc. be taken.
5% of water = 1·524 specific gravity = 0·038 gram. if 25 cc. be taken.

The original skim milk had a specific gravity of 1038·2, and yielded 11·46 per cent of solids not fat, and in order to bring it to the standard of 9·4 it had to be diluted with distilled water in the ratio of 812 to 188, this being equivalent to an adulteration of no less than 18·8 per cent. of water.

If the original skim milk had been taken for the determination of the specific gravity of the mixtures of milk and water, the following figures would have been obtained :—

TABLE II.

Per cent. of Water.	Specific Gravity.	Total Solids.
0	1038·20	11·46
5	1036·29	10·89
10	1034·38	10·31
15	1032·47	9·74
20	1030·56	9·17
25	1028·65	8·59
30	1026·74	8·02
35	1024·83	7·45
40	1022·92	6·88
45	1021·01	6·30
50	1019·10	5·73
55	1017·19	5·16
60	1015·28	4·59

It will thus be seen that the specific gravity 1030·48 and the solids of 9·4 are as a rule far too low, and that skim milks of really good quality and such as are furnished by good and healthy cows are almost invariably of higher gravity and yield a much larger percentage of solid matter; so that the gravity of 1030·48 and the solids of 9·4 are far too favourable to the vendors of milk, since they allow, in some cases, of its adulteration with over 20 per cent. of water, which, adopting the standards above referred to, would not be noticed.

It is only a cow in its poorest condition which furnishes milk of such a low quality, and the adoption of the standard of 9·4 per cent. of solids not fat would act as a premium upon adulteration, and would lead eventually to the serious impoverishment of the milk as sold to the public throughout the country. A higher standard ought, therefore, to be adopted, and not one based upon an exceptionally impoverished milk. The milk as ordinarily sold is a mixture of the milks of several cows, and such milk never yields so small a proportion of solids not fat as 9·4. We would recommend, therefore, that a standard of 10·4 be adopted, which would afford the public greater protection, but would still allow of the addition of considerable quantities of water to really rich milks.

Results equally accurate may be obtained by taking the specific gravity of the *serum* of milk. The casein and butter are easily removed by the addition of a few drops of acetic acid, a quantity indeed so small as scarcely to affect the gravity of the serum, or, still more unobjectionably, by placing in the milk a small strip of the inner membrane of the stomach of the calf or pig.

In relying upon the specific gravity test and even upon the tota solids in determining whether water has been added or not, the chie fallacy to which the observer is subject is that occasioned by th addition of saccharine matter, which would cause the gravity to be higher and the amount of solids greater.

But in the case of whole milk there are other sources of fallacy to which reference to some extent has already been made, and against which it is necessary to guard.

Thus a milk may possess the proper specific gravity, and yet be deficient of cream, which may have been abstracted; again, it may be several degrees lighter than ordinary, and yet may be perfectly genuine, this arising from the presence of an unusual quantity of fatty matter.

In order to guard against these fallacies, therefore, *it is always necessary not only to take the weight of the skim milk, but also to measure the quantity of cream or fat, or to weigh the fat.*

The instruments by which the weight of milk is taken and the cream measured have already been described. These instruments are many of them incorrect, and it would be a great protection to the public if they were all stamped in the same way as weights are, as a guarantee of their accuracy.

Another method by which the quantity of water may be indirectly estimated is by determining quantitatively, in the manner already described, the amount of solids not fat present.

Taking 9·4 as the amount of total solids not fat, below which in genuine milk of the poorest quality they never fall, the following table gives the proportion between the amount of added water and the solids not fat in a special case:—

Solids not fat.	Added water.
9·40	None.
8·46	10%
7·52	20
6·58	30
5·64	40
4·70	50
3·76	60
2·82	70
1·88	80
0·94	90

The formula for the above calculations is $9{\cdot}4 : 100 = a$ (amount of solids not fat) : x (amount of genuine milk in the sample).

If treacle be purposely added in the right quantities, then indeed it would be very difficult to establish the fact of the adulteration of milk with water; and if cane sugar were employed, the object could only be accomplished by the transformation of the sugar into glucose, and its estimation by the copper test in that form. The polariscope, as also the solubility of lævulose in alcohol, would in some cases afford valuable information.

When any considerable addition of water has been made to milk, or when milk is either poor in quality or has been deprived of a portion of its cream, these facts are conclusively established by the concurrent use of the old and very simple instruments, the hydrometer and creamometer, the use of which it has been too much the fashion of late to decry. By means of these instruments, the former applied to the skim milk, results accurate enough for all practical purposes may be rapidly obtained, and with the expenditure of exceedingly little time and trouble, whereas the quantitative estimation of the fat and total solids is comparatively tedious and difficult, and involves the possibility of error in the drying of the milk and the several weighings required.

Horsley's method.—Mr. Horsley judges mainly of the quality of milk by the amount of fat therein contained, and he has devised a very simple and ingenious method of determining the same. He takes 250 grains of milk, equal to about an ordinary tablespoonful, pours it into a glass tube, similar in size and form to a creamometer, but with the addition of two lines, one being the measure of the 250 grains of milk, and the other that of the 250 grains of ether subsequently added. To the milk an equal bulk of methylated ether of specific gravity 0·730 is added, and the mixture is briskly shaken for four or five minutes, whereby the oil globules are broken up and dissolved by the ether. A similar quantity of methylated spirit of about 0·838 specific gravity is next added, and the mixture again shaken for at least five minutes. The solvent power of the ether for the fat is thus destroyed, the fat collects on the surface as pure butter, and its amount is estimated by measurement, one line of Mr. Horsley's instrument being equal to 4·15 grains of butter. Milk of good quality, he considers, should yield 10 per cent. of cream, a quantity which would usually contain about 3·32 per cent. of butter fat.

If by this proceeding Mr. Horsley found the fat reach the above quantity, he would as a rule be satisfied and would pronounce the milk to be genuine and of good quality; but this conclusion, like those which he condemns, based upon the results obtained by the use of hydrometers and creamometers, would sometimes prove to be fallacious, since it is a very frequent thing to meet with milks yielding 10 per cent. of cream which have yet been adulterated with large quantities of water, nay, which may consist of nearly one-half water.

At the same time that the fat is separated and collects on the surface, the casein is precipitated, the sugar and salts of the milk being held in solution in the mixture of ether and alcohol. The casein in a state of comparative purity may be readily separated by filtration, and its amount estimated after drying. The sugar and salts may likewise be estimated by the evaporation of the mixed ether and alcohol. But then it may be said that the ordinary chemical method of drying a portion of the milk, extracting first with ether and then with dilute alcohol, and lastly incinerating, is not more troublesome or difficult, and gives results of extreme accuracy.

Mr. Horsley directs that the milk should be shaken well for about ten minutes. This seems simple enough, but anybody who adopts this proceeding will find that his arms will ache considerably at the end of that time, and it must be remembered that the whole success of the method depends upon the completeness of the agitation. We find that while this method gives tolerably accurate results for ordinary milks, it is not well suited for the examination of creams, it indicating a far less amount of fat than is ordinarily present.

On the detection of sugar.—The sugar used is usually brown sugar or treacle; the presence of these may be determined as follows:—The casein and butter are to be precipitated by means of acetic acid, and the serum evaporated, a very gentle heat only being used, and the colour of the residue particularly noticed; if it is darker than ordinary, the presence of sugar may be suspected.

The residue may then be dissolved in distilled water. In one portion the sugar of milk is estimated in the usual manner by means of the copper test; the second is boiled with a little dilute sulphuric acid, as described under the head of 'Sugar,' in order to convert the cane and milk into grape sugar. This is then in its turn estimated by the copper test, the difference between the two estimations indicating the amount of cane sugar present. But it must be remembered that milk sugar reduces a much larger proportion of the copper test than glucose and galactose, the proportion being as 134 is to 100.

100 parts of grape sugar correspond to 95 parts of cane sugar and to 134 parts of milk sugar.

If treacle be used, there will be found a large excess of both grape and cane sugar.

On the detection of starch.—For the detection of starch in milk and cream, the microscope furnishes the readiest and most certain means. A little of the milk, spread out in a very thin stratum, should be examined under the microscope, the examination being aided by the use of tincture of iodine. Of course we must not expect to find unaltered starch corpuscles in milk, the starch being added in the form of a decoction. For the quantitative determination of the starch, which will not often be required, we may proceed as follows:—

20 cc. of the milk must first be evaporated to dryness on a water-bath. The milk sugar must then be removed by digestion with weak alcohol; the residue dried, and from it the fat must next be separated by means of ether, and the remainder is to be boiled for several hours with a few drops of sulphuric acid in order to convert the starch into grape sugar, in the manner already described for the conversion of cane sugar into glucose. 90 parts of starch yield 100 parts of grape sugar.

On the detection of gum arabic.—The serum of milk obtained by precipitation of the curd with a little acetic acid is to be treated with a solution of acetate of lead; the precipitate is collected on a filter, washed, suspended in water, and the lead removed by means of sulphuretted hydrogen. The sulphide of lead is separated by filtration, the filtrate evaporated, and the residue, after drying and weighing, gives the quantity of gum.

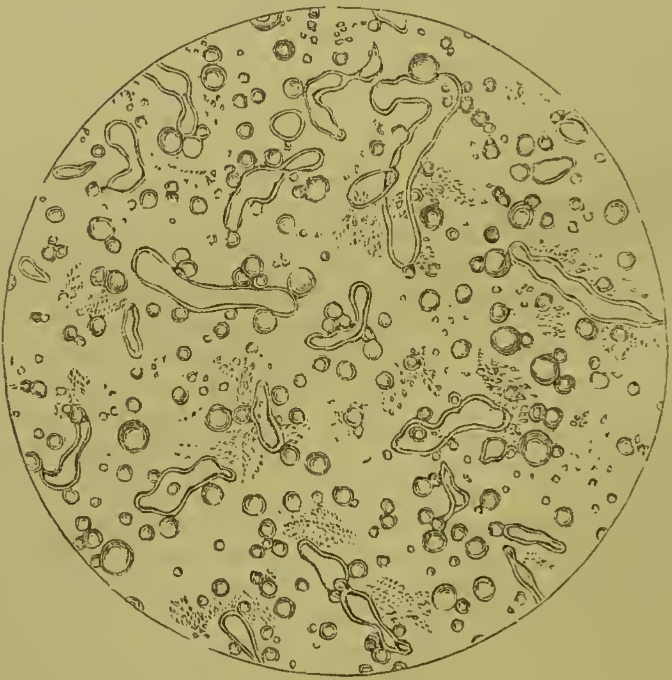
On the detection of gum tragacanth.—Gum tragacanth is really a mixture of gum and starch, and each of these substances would have to be separately estimated by the methods already described.

For the detection of the tragacanth we are recommended to boil the milk, and leave it at rest for some hours, when a gelatinous translucent deposit will be formed, which, being washed with a small quantity of water and tested with a few drops of solution of iodine, produces a blue colour, because gum tragacanth contains starch. The starch of gum tragacanth is plentiful and is in the form of starch corpuscles; these are rather small, but vary much in size; many are irregular, some are rounded, others are somewhat polygonal, while a few are muller-shaped; in the more perfect grains a rounded hilum is distinctly visible.

On the detection of cerebral matter.—The presence of cerebral matter in milk may be determined with certainty by means of the microscope, portions of the nerve tubules being readily discovered with that instrument, as shown in the engraving (fig. 132).

Fig. 132.

Milk Adulterated with Sheep's Brains.



On the detection of chalk.—If the milk be diluted with water and set aside for some hours, part of the chalk, if present, will have subsided as a precipitate, when it may be sufficiently identified by its appearance and its effervescence with acids. Or a portion of the milk may be evaporated to dryness, the residue incinerated, and the chalk estimated from it in the manner pointed out in the articles on 'Tea' and 'Water.'

On the detection of carbonate of magnesia.—This has been said to occur only in cream; it would be detected by the insolubility of the ash in water, its effervescence on the addition of an acid, and lastly by the crystalline precipitate which is thrown down from its solution in hydrochloric acid on the addition of a solution containing ammonia, chloride of ammonium, and phosphate of soda.

On the detection of salt.—The saline taste of the ash will show the presence of salt if that substance has been employed. This must be determined from the ash by the process described under 'Water.'

On the detection of lead, copper and zinc.—Since milk is not unfrequently contaminated with these metals, the analyst may be called upon to determine whether they are present, and especially zinc, or not. The methods for the detection and estimation of the two former of these metals will be found given under the heads of 'Water' and 'Bread.'

The presence of zinc may be detected in the solution of the ash of the milk in hydrochloric acid by rendering it alkaline with caustic potash, filtering, and adding a few drops of a solution of sulphuretted hydrogen to the filtrate. A white precipitate, consisting of sulphide of zinc, will prove the presence of that metal, and from the weight of the precipitate its amount may be determined. See 'Vinegar.'

On the detection of annatto.—The presence of annatto is rendered probable when the milk, evaporated down to a small quantity, presents a reddish or orange-red colour; if this colour is materially altered on the addition of an alkali or an acid to the milk, being rendered purplish by the one and of a brighter red by the other, its presence is certain. Lastly, by means of alcohol, the colouring matter may be dissolved out of the soft residue of the evaporated milk, and the effects of the reagents mentioned tried upon the alcoholic extract.

On the detection of turmeric.—If turmeric has been used in substance to colour milk, it would be possible to detect the turmeric cells. However, it is best to proceed by the method indicated for the discovery of annatto. The chief difference is that the turmeric is rendered deep brown by alkalies.

It is of course rarely, if ever, necessary to examine milk for more than two or three of the articles above enumerated. In general it is sufficient to determine whether water, the ordinary adulteration of milk, has been added or not.

THE DETECTION OF THE ADULTERATIONS OF CREAM.

Sufficient has already been said under the heads of the analysis of milk and the detection of its adulterations to enable the analyst to detect and estimate all the known adulterations of cream.

CHAPTER XIX.

BUTTER AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any foreign substance, as the fat of beef, mutton, or pork; flour, starch, or any mineral matter other than salt, which should not exceed 4 per cent. in fresh, and 8 per cent. in salt butter; curd, which should not exceed 4 per cent.; and water, which should not be more than 12 per cent.

As the method of making butter may not be known to many of the readers of this report, we will proceed, before entering upon the consideration of its adulterations, to give a very brief outline of the manner in which butter is usually prepared.

Butter is made for the most part from cream; the cream is collected from time to time, and placed in a covered jar, until sufficient has been obtained, when, having become sour by keeping, it is submitted to the process of churning.

Butter is also prepared in small quantities from sweet cream, and this kind is esteemed a great delicacy. Very excellent butter is likewise sometimes made from full or entire milk; the disadvantages of this method are—the large quantity of fluid to be acted on by the churn, which renders it necessary that steam or some other powerful mechanical means should be had recourse to, and the length of time which elapses before the butter forms.

As soon as the butter has formed, it is removed from the churn, and well washed in water, it being kneaded at the same time until as much as possible of the adherent and incorporated whey is removed; this is known by the water ceasing to become turbid and milky. If intended for salt butter, the salt should be added as soon as possible after churning and washing, as, left for any length of time, the butter is apt to become rancid. Great attention should be paid to the quality of the salt used; the best descriptions are rock salt and that prepared from salt springs. Sea salt, generally, is not so good, on account of the presence of sulphate of magnesia, which renders it somewhat bitter, as well as of chloride of calcium, which has a strong affinity for water, even attracting it from the atmosphere.

It would be out of place in this report to enter into the practical minutiæ of butter-making, such as the temperature at which the cream or milk should be churned, the best kinds of churn, the methods of churning, &c., all points of the greatest importance for the agriculturalist and the dairyman.

COMPOSITION OF BUTTER.

Butter consists of the *glycerides* of certain *fatty acids*, principally of *stearic, palmitic,* and *oleic acids*, with smaller quantities of *butyric. capric, caproic,* and *caprylic acids*; these latter are all distinguished from the former acids by their volatility. According to the analysis of Bromeis, they amount to only 2 per cent., they being embraced by that chemist in the term 'butyroleic acid.' But Messrs. Angell and Hehner have proved, as will be shown hereafter, that these volatile acids are present in much larger quantities, amounting on an average to 9·3 per cent.

The true melting point of butter, taken in the manner described hereafter, we found to range from 32·8 to 34·9, the mean of all the observations made being 33·7° C.

The oily or buttery part exists in milk in the form of innumerable very distinct globules, of various sizes. The effect produced by churning is to break down these globules, which then run together, and thus form butter. The operation of the churn is therefore chiefly, if not entirely, mechanical.

THE ANALYSIS OF BUTTER.

The analysis of butter is very nearly the same as that of milk, since it contains for the most part the like constituents, although in very different proportions. It is, therefore, not necessary to enter into any lengthy details on the subject. The water is to be estimated by the loss on evaporation, the fat by extraction with ether; the curd and salt are left on the removal of the fat; the quantity of the former may be estimated by incineration, and the mineral matter remaining may be calculated as salt, of which it usually almost entirely consists.

Butter, when fresh, is of a yellowish colour, having a peculiar and characteristic sweet odour, but when exposed for a long time to the air it loses gradually its colour, becomes white, and acquires a tallowy odour, which was at one time considered to be characteristic of beef, mutton, and other analogous fats; and samples of perfectly genuine butter, when thus changed in colour and odour, have unquestionably in many cases been declared to be adulterated. In fact, by many analysts the tallowy smell was considered to afford a conclusive proof of the adulteration of any butter with some foreign animal fat.

THE OCCURRENCE OF CRYSTALS IN BUTTER.

It is very generally believed that the occurrence of needle-like crystals, often arranged in the form of spherules or stellæ, is a certain proof of the adulteration of butter and of the presence of lard or some other foreign animal fat. This belief, however, is entirely erroneous; and although no crystals are found in freshly-made butter, yet they appear in it if kept for any length of time, and they are especially abundant in all butters which have been fused and allowed again to solidify. On the surface of all such butters a shiny scum or pellicle may be seen, composed in large part of such crystals, which are likewise to be found abundantly diffused throughout the whole mass of the butter. Again, they are frequently met with in great numbers in cream. They polarise light. Messrs. Angell and Hehner make the following remarks in reference to crystals in butter:—If a small quantity of a fat containing crystals be placed upon a slide, a drop of castor or olive oil be added, and the whole then pressed out by means of a thin glass cover, the depolarisation of light is much enhanced. A revolving black cross, not unlike that of starch grains, is seen in great perfection. These crosses are most clearly defined in the crystals obtained from butter.

Dr. Campbell Brown, in his essay on the 'Adulteration of Butter,' remarks:—'A microscopic examination with polarised light is the most reliable means of distinguishing pure butter from that which contains an admixture of less easily digestible and palatable fats.' But this statement, as we have seen, is erroneous.

THE ADULTERATIONS OF BUTTER.

Adulteration with water.—One of the most frequent practices had recourse to in the case of butter is to incorporate with it large quantities of *water*; the incorporation is effected in the following manner: the butter is brought to the melting point, water and *salt* are then stirred in until the mixture becomes cold.

In reference to the adulteration of butter with water and salt, Professor Calvert, in his evidence before the Parliamentary Committee on Adulteration in 1855, made these remarks:—'The quantity of water and salt that such an article as butter ought to contain is 2½ per cent. of salt, and 10 per cent. of water. In the butter supplied to these Unions the quantity of salt varied from 2 up to 14 per cent., and the water from 10 to 15 per cent.'

A butter factor wrote to us some time since, stating that 50 per cent. of water may be incorporated with butter in this way; but when you buy, say half a pound of butter, a considerable part of the water of adulteration escapes, and if you put it in paper more will be lost.

Adulteration with starch.—Another adulteration to which butter is occasionally subject, especially the inferior kind known as Bosh, consists in the addition of *starch*, usually *potato flour*. This adulteration is practised only at particular times, and is dependent upon the wholesale price of butter.

Adulteration with curd.—Again, butter has been known to be adulterated sometimes with curd. This adulteration is particularly mentioned by Sir John Gordon, mayor of Cork, in his evidence before the Parliamentary Committee above referred to.

Adulteration with animal fat.—Lastly, animal fats are not unfrequently employed, as the fat of beef, mutton, veal, lard, &c.

Beef fat is sometimes prepared on a large scale and made up in imitation of butter, being known and sold under the name of 'Butterine.' This article is mainly the olein of the fat, with only a small proportion of the stearin. When freshly prepared it is sweet and palatable, and being sold at a much lower price than butter itself, it is in some cases a useful substitute; but it is to be feared that such a preparation would be used in some cases for the adulteration of butter.

Results of the Examination of Samples.

The examination of *forty-eight* different butters, both salt and fresh, made some years since, and published in the Report of the Analytical Sanitary Commission of the 'Lancet' on the adulteration of butter, furnished the following results:—

All the *salt butters* examined contained variable and usually very large quantities of *water*, the amount ranging, with one exception, from 8·48 to 28·60 per cent.

The *fresh butters* likewise contained variable and often considerable quantities of *water*, but in most cases very much less than the salt butters, the quantities ranging from 4·18 to 15·43 per cent.

The quantity of *salt* contained in the *salt butters* varied from 1·53 to 8·24 per cent., showing that no fixed rule is acted upon in salting butter.

In the *fresh butters* the *salt* varied from 0·30 to 2·91 per cent.

The percentages of butter fat contained in the samples ranged from 67·72 to 96·93; that is, some of the samples contained 20, 30, and in one case even nearly 35 per cent. of water and salt.

Now the presence of water in butter, in excess and when purposely introduced, assuredly constitutes an adulteration as much as does the addition of starch or animal fats.

To many of the samples of salt butter examined, a quantity of salt over and above the amount necessary to ensure the preservation of the butter had no doubt been purposely added to increase the weight and bulk; in fact, for the sake of adulteration.

It is equally certain that much of the water met with in many of the samples had been added for the same purpose. The quantity of water present in some inferior descriptions of butter, as especially Bosh and the worst kinds of 'Hollands,' is really surprising, amounting in some cases to more than a third of the article.

The samples of which the analyses are given in the following table were recently analysed for the purpose of determining the percentage composition of butters as ordinarily met with, and very many of which it was known beforehand, from the sources from which they were obtained, were perfectly genuine. It must not, therefore, be concluded that these analyses represent the condition of the butters sold in London and other populous cities. With three exceptions they were all fresh butters, which are much less liable to adulteration than salt butters:—

Table of Analyses of Butter.

	Hassall. Fresh Isle of Wight Butters.					
Water . . .	16·80*	11·68	13·62*	13·68*	16·92*	11·39
Fat . . .	77·64	84·97	83·97	82·30	80·07	85·29
Curd . . .	1·89	1·18	1·54	2·42	0·52	1·75
Salt . . .	3·67	2·17	0·87	1·60	2·49	1·57

	Angell and Hehner.					
	Isle of Wight.	Isle of Wight.	Isle of Wight.	Sussex.	Jersey.	Normandy.
Water . . .	9·709	10·063	12·984*	11·168	6·463	9·305*
Fat . . .	84·740	86·466	83·871	83·683	89·480	84·643
Curd . . .	3·462	2·799	2·721	3·143	2·459	5·137
Salt . . .	2·085	0·672	0·424	2·006	1·598	2·915

	Angell and Hehner.						
	Isle of Wight.	Isle of Wight.	Guildford.	Winchester.	Winchester.	London.	London.
Water . .	9·193	7·683	8·580	6·370	8·615	23·981*	42·358*
Fat . . .	84·680	88·449	85·480	90·197	87·223	67·580	47·119
Curd . . .	2·917	1·908	2·789	1·611	2·054	6·880	7·834
Salt . . .	3·210	1·960	3·151	1·822	2·108	1·559	2·689

	Salt Butters.		
	Hassall.	Angell and Hehner.	
		Jersey.	Ventnor.
Water . . .	6·50	10·445*	3·831*[1]
Fat	85·38	78·491	86·280
Curd. . . .	2·84	2·536	3·289
Salt.	5·28	8·328	6·600

*[1] This butter had nearly the normal fusing point of genuine butter, but it furnished 92·87 per cent. of fatty acids, equivalent to 67 per cent. of foreign fat.

	Butterine.*[1]
Water	5·838
Fat	92·776
Nitrogenous matter	0·555
Salt	0·831

If the reader will now refer to the definition of the adulteration of butter given which forms the first paragraph of this article, he will be enabled to determine for himself which of the samples were adulterated and in what manner. For greater convenience, however, we have distinguished all the adulterated butters by an asterisk.

Two samples of butter from Portsmouth, recently submitted to us for analysis, and which were the subject of a successful prosecution, were found to have the following melting points, 37·7° and 37·5° C. These fusing points were sufficient to establish the fact of the adulteration of these butters with a considerable proportion of foreign fatty matter, but the second butter was also tested by Angell and Hehner's method, and was found to yield 89·9 per cent. of fatty acids, equivalent to 38 per cent. of adulteration.

There is a practice rather extensively adopted of making a so-called fresh from salt butter; although this is not an adulteration, it is yet a deception. The process by which the transformation is effected is rather ingenious and somewhat amusing.

Salt butter of very inferior quality is repeatedly washed with water in order to free it from the salt. This being accomplished, the next process is to wash it frequently with milk, and then to add a small quantity of sugar.

Perceiving, then, to what an extent salt butter is adulterated, with both water and excess of salt, we very much doubt whether any saving is effected by the use of this description of butter; although nominally cheaper, it is questionable whether it be not really dearer in the end.

THE DETECTION OF THE ADULTERATIONS OF BUTTER.

The chief adulterations of butter are with water, starch, excess of salt, and animal fats.

On the estimation of water.—After being churned, butter is kneaded in water in order to get rid of the whey with which it is incorporated; the adoption of this process accounts for the presence of a small quantity of water in butter only.

There are two methods by which the quantity of water in butter

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The reason of its having the same melting point as butter arises from the fact that the foreign fat consisted chiefly of olein.

*[1] This butter had a melting point of 29·5° C, and furnished nearly 95·5 per cent. of fatty acids, proving that it consisted almost entirely of foreign fat, principally olein, as shown by the fusing point.

may be determined; one simple and popular, the other more scientific and exact.

First method.—A fair sample of the butter should be taken from the centre of the piece or lump, as near the surface part of the water might have escaped. It is to be melted, and a bottle filled with it. This is to be placed, for half an hour or so, near the fire; the water and salt will become separated from the butter, and sink on account of their greater weight or specific gravity. Owing to the water being mixed with a little whey, it usually presents a white and milky appearance, very distinct from that of the butter itself, which floats upon it, and which is more or less yellow; the quantity of water is then roughly estimated by noticing the height it reaches up the bottle. In some cases it will be found that the water constitutes a fourth and even a third of the article.

Second method.—3 or 4 grammes of the butter, taken from near the centre of the piece, must be placed in a small glass or porcelain dish or capsule, over a water-bath, until they cease to lose weight; the butter and the capsule must then be weighed, and the weight of the capsule deducted; the deficiency on the original quantity taken represents the amount of water contained in the butter.

It is possible that in some cases the question might arise as to whether the fluid separated on melting butter, consists of water or whey, or of both mixed; this point may be determined approximately by taking the specific gravity, or, more precisely, by estimating the amount of sugar of milk present in the liquid. This is effected by the processes described in the articles on 'Sugar' and 'Milk.' One thousand parts of whey usually contain about fifty parts of sugar of milk.

On the detection and estimation of starch.—Starch in butter may be readily detected and its amount estimated. For its detection, nothing more is necessary than to examine a minute portion of the butter spread out in the thinnest possible layer, and covered with a plate of thin glass, with a half or quarter-inch object glass, tincture of iodine being in some cases employed at the same time. The starch will be recognised either by the form of the granules or by the action of iodine.

To estimate its quantity, the following proceeding may be adopted:—A weighed quantity of butter is taken, dried, and the fat removed by means of ether, and the starch in the residue is converted into glucose in the manner described under the head of 'Sugar.'

On the estimation of salt.—A weighed portion of the butter must be incinerated, and the salt determined by an estimation of the chlorine by means of nitrate of silver. In general the whole of the ash of salt butter may be counted as salt.

Estimation of the curd.—A weighed quantity of the butter is dried on the water-bath and the fat removed by means of ether, the residue consisting, for the most part, of casein and salt. It is incinerated, when the loss of weight will represent the amount of casein.

If starch be present at the same time, it will remain with and be calculated as casein. It should therefore be estimated by conversion into glucose in another portion of the butter, and the amount subtracted from the amount of combustible substances found in the first experiment.

THE DETECTION AND ESTIMATION OF FOREIGN FATS.

Nearly the whole of the following matter, having reference to the separation of the stearin and palmitin from the olein and the determination of the fusing points of fats, was first published in 'Food, Water, and Air,' for November 1874.

The difficulties attending the detection of animal fats in butter are very great, and have hitherto been deemed by many to be insuperable; indeed, this latter opinion has been distinctly and recently advanced by Professor Voelcker and Mr. Wanklyn in their evidence before the Parliamentary Committee on Adulteration, which has so lately had the subject of the adulteration of food under investigation. Thus Professor Voelcker, in reply to the question, 'Is it very difficult to distinguish between butter fat and other sorts of fat?' remarked, 'I do not know of any very decided test whereby you can distinguish the olein and other simple fatty substances of butter from other fats, therefore I am somewhat astonished that analytical chemists can give so positive a statement with regard to the adulteration of butter fats.' While Mr. Wanklyn, in reply to the question, 'How is it that prosecutions of butter have failed under this Act, do you imagine?' said, 'They have failed because there is no method for ascertaining the presence of foreign fat in butter;' and when asked if he had heard the evidence given by Dr. Hassall, he said he had, and when the chairman remarked, he (Dr. Hassall) says that there is no difficulty, Mr. Wanklyn replied, 'I believe that he is labouring under a mistake;' and again, when the chairman observed, 'Then you think that Dr. Voelcker is right and Dr. Hassall is wrong?' he said, 'I have no doubt whatever upon this subject.' And lastly, in answer to further questions, Mr. Wanklyn again emphatically stated that 'there are no trustworthy chemical tests for foreign fats in butter.' When the chairman observed, 'You have no doubt about it?' he answered, 'I have no doubt whatever about it, and I would undertake to prepare for Dr. Hassall samples of foreign fats that he would mistake for butter, or to give him a set of samples of butter and other fats, and he would certainly not distinguish them.'

The evidence which the author gave on this subject followed that of Professor Voelcker, and preceded that of Mr. Wanklyn, and was as follows:—'A statement was made by Dr. Voelcker in his evidence given before this Committee a few days since, that there were no tests whereby the admixture of other fats with the fat of butter could be detected and determined; to that statement I demur. I may say more than that, there are tests whereby the adulteration of butter with animal and vegetable fats may be accurately determined, and I beg now to hand in a short statement of a method of analysis of butter, not my own method, but that of an assistant and pupil of mine, Mr. Otto Hehner, and Mr. A. Angell.'

When it is remembered that the various animal and vegetable fats, such as beef and mutton fat, resemble butter in being composed mainly of stearin, palmitin, and olein in variable proportions, it cannot be wondered at that the difficulty of determining the presence in butter of these and other analogous fats has been deemed to be almost insuperable. Putting aside for the moment the fact of the presence in butter of the volatile fatty acids, the only difference which remains between butter and most other animal and vegetable fats consists in the proportions, which vary in the case of each fat, of the glycerides of the several fixed fatty acids before-named.

Now it might be thought by some, at first sight, to be an easy matter to determine the relative proportions contained in different fats of stearin, palmitin, and olein, and in this way to arrive at a satisfactory conclusion as to the presence of foreign fats in butter, but in reality the task is one of extreme difficulty, in fact, one which we have found to be, in the attempts which we have hitherto made, insurmountable.

Separation of stearin and palmitin from olein.—We first attempted to separate the stearin and palmitin of butter from the olein by deposition from an ethereal solution.

One gramme of butter, dissolved in 6 grammes of hot ether, furnished no deposit when cooled in water to 18·3° C.

Mutton caul fat and ether in the same proportions gave a considerable deposit.

One part of mutton caul fat required 15 parts of hot absolute alcohol for complete solution.

A mixture of equal parts of ether and alcohol, used in the proportion of 1 to 6, yielded a deposit with both butter and mutton caul fat.

One gramme of a mixture of 2 parts of butter and 1 part of stearin, dissolved in 6 parts of ether, furnished 0·31 gramme of deposit, equal to nearly the original amount of stearin used.

One gramme of mutton caul fat, dissolved int he mixture of alcohol and ether, deposited 0·47 gramme of stearin.

One gramme of the following fats, dissolved in 3 grammes of ether, furnished the subjoined results:—

Butter	None.
Ox kidney fat	0·174 stearin
Ox caul fat	0·389 "
Pig kidney	0·217 "
Pig caul	0·237 "
Mutton caul	0·222 "
Lard	0·212 "
Dripping	0·225 "

A mixture of 1 part of dripping and 2 parts of butter did not furnish any deposit.

The ethereal solutions in these experiments were all brought to a temperature of 18·3° C.

Three butters dissolved in three parts of ether, and placed in a refrigerator containing ice, furnished the following percentages of deposit:—

1	11·2 per cent.
2	7·8 „
3	6·5 „

While 5 different fats, treated in the same manner, furnished the following much larger quantities:—

Mutton kidney	53·6 per cent.
Mutton caul	48·7 „
Ox kidney	39·8 „
Ox caul	49·3 „
Lard	21·8 „
Mutton dripping	27·7 „

One part of 7 samples of butter, dissolved in 3 parts of ether, and cooled down in a refrigerator with ice, furnished the following deposits, these being the aggregate of five different operations of cooling, extending over about 60 hours.

1	62·55 per cent. deposit.
2	60·85 „ „
3	35·50 „ „
4	49·25 „ „
5	51·95 „ „
6	49·30 „ „
7	46·55 „ „

The amount of the first deposit obtained was found to vary with the length of time during which the butter was allowed to remain in the refrigerator, the deposit, as a rule, being greater the longer the period.

Another series of experiments was made with a view to determine the proportion of olein present in butter and other fats, and in these alcohol was used as the solvent, in the proportion of 40 grammes of fat to 1,000 cc. of absolute alcohol, the mixture being cooled down, as usual, for about twelve hours in the refrigerator.

Butter 1	32·10 per cent. olein.
„ 2	32·62 „ „
„ 3	36·59 „ „
„ 4	34·87 „ „
„ 5	38·82 „ „
„ 6	33·59 „ „
„ 7	36·94 „ „
Mutton caul fat	25·83 „ „
Lamb caul fat	23·15 „ „
Beef kidney	30·08 „ „

The specific gravity of the olein, at 15·5° C., thus obtained from the butters was, in three cases, 0·9148, 0·9126, and 0·9134, whilst the specific gravity of olein from olive oil was 0·9114. The specific gravity of the stearin simultaneously obtained from the butters was 0·9213, 0·9153, and 0·9384.

The specific gravity of pure stearin was 0·9268, and that of pure palmitin 0·9117.

The specific gravities of the three butters themselves were 0·9256, 0·9236, and 0·9210.

Several other experiments were made in which the quantity of alcohol was increased from 1,000 cc. to 1,500 cc., the latter quantity being used on the supposition that the stearin deposited would carry down less of the olein, it being found, on taking the fusing point of the deposits, that they contained a large admixture of olein. These experiments gave the following numbers:—

1.	40·08 per cent. olein	Specific gravity,	0·9219
2.	44·34 „ „	„	0·9191
3.	37·85 „ „	„	0·9208

Specific gravity of the stearin deposited was 0·9392, 0·9332, and 0·9296 respectively.

The specific gravity of three other samples of butter was as follows:—0·9342, 0·9202, 0·9328, while the amount of oleine obtained and its gravity were as given below:—

4.	34·93 per cent. olein	Specific gravity,	0·9176
5.	40·34 „ „	„	0·9209
6.	43·77 „ „	„	0·9199

Specific gravity of the stearin deposited was 0·9225, 0·9277, and 0·9310.

The oleins obtained from the solutions of butters in 1,500 cc. of alcohol were afterwards redissolved in a smaller quantity of alcohol, and the solution again placed for twelve hours in the refrigerator, with the result of obtaining further deposits of stearin, and of course diminished amounts of olein. Thus 100 parts of the olein firs obtained were reduced by the second operation to 97·2 and 84·4 respectively. The olein of mutton caul and of dripping was reduced from 100 parts to 58·9 and 43·6 respectively.

The results of the preceding experiments may be thus summed up:—That it is most difficult, if not impossible, to separate completely the stearin and the palmitin from the olein by the methods adopted; these methods being, for the most part, more definite, the author believes, than any which have been hitherto resorted to. At the same time they serve to show that the proportion of olein in butter is much greater than in most animal fats, these latter containing an excess of stearin and palmitin. Thus, in reality, it is in many cases quite possible by these methods to determine beyond all doubt the fact of the adulteration of butter by the fats in question.

Again, the observations above recorded are sufficient to show that the specific gravity of the different fats does not furnish sufficient data on which to determine the admixture of butter with other animal fats.

Not only is it all but impossible to completely separate the stearin and palmitin from the olein, but that portion of the two former glycerides which deposits from the solution is invariably admixed with large quantities of olein, so that the weight of these obtained cannot be taken as representing pure stearin or palmitin; this being proved by taking the melting points of the deposits. On the other hand, the olein retained with equal obstinacy a portion of the more solid fats.

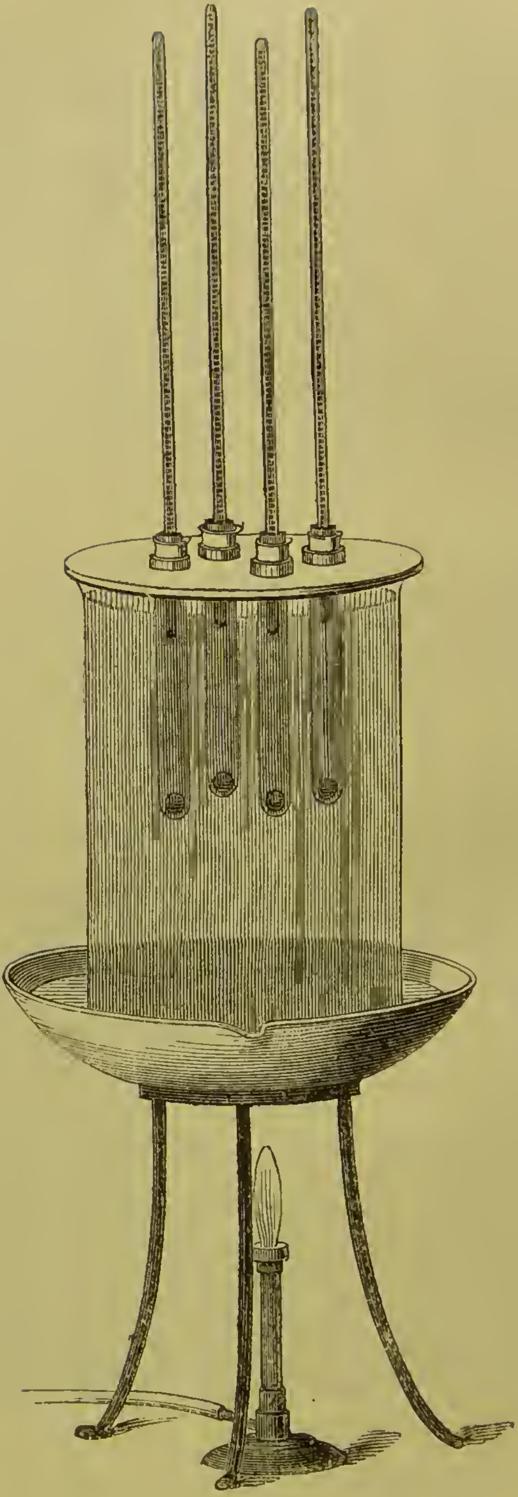
Had it been possible by these methods to have estimated accurately the exact quantities of stearin, palmitin, and olein contained in the different fats, we should, no doubt, have arrived at the desired results, and should have been able to have determined the extent of the admixture of most animal fats with butter.

DETERMINATION OF THE FUSING POINTS.

Failing to arrive at conclusions sufficiently definite by the methods above referred to, we next directed our attention to the fusing point of butter and other fats, from which it appeared to us that valuable data, of a much more reliable character than those usually given, might, by stricter methods of investigation, be arrived at. It has been stated that butter and foreign fats consist mainly of palmitin, stearin, and olein in variable proportions. Now these have different melting points, the difference between that of stearin and palmitin as compared with olein being very considerable. Thus the melting point of stearin is about 63° C., of palmitin nearly the same, while olein is liquid at ordinary temperatures and solidifies only at a temperature much below the freezing point. Knowing, therefore, the melting point of any given fat and of its prime constituents, it would appear to be possible to arrive approximately at the percentage composition of that fat and even of a mixture of fats. But we have not been contented to rely upon a rule of this kind, which would be vitiated to some extent by the presence of the volatile acids in butter, and we have therefore experimented specially with the actual fats mixed together in certain known proportions.

The manner in which the melting point of butter and the other fats has hitherto been usually determined has been very inexact, and the method pursued has been such as to render it impossible that the observations of any two observers could correspond. The method adopted by Messrs. Angell and Hehner, with a view to the more accurate determination of the fusing points of fats was as follows: They used a bulb having a weight of 3·4 grammes and a volume of 1 cc., placed this on the surface of the fat contained in a test-tube, and observed the point at which the weight became immersed in it as

Fig. 133.



it slowly melted, the tube being suspended in a vessel of water, the temperature of which was gradually raised, and in which the thermometer was placed. This method has no doubt the merit of furnishing results which are strictly comparative, and which would even yield in the hands of other observers corresponding results. We have adopted a somewhat different method. In place of using a weight we have employed a float, having a weight of 0·18 gramme, and a volume of about 0·5 cc. This is placed in the bottom of the test-tube, a little melted fat is poured upon it, which is allowed to become solid in order to fix the float, the tube being afterwards filled up with the fat, the melting point of which is to be observed. Lastly, the bulb of the thermometer was immersed *in the fat* in the tube, in place of in the water surrounding it. The latter difference in the mode of procedure is one of considerable importance, as the water naturally has a higher temperature than the fat itself, which derives its heat from the water, a difference which amounts to several degrees.

But in the course of the many observations made, it became evident that there were still disturbing causes at work, which led to variations in the results obtained, which were at first surprising and difficult to explain. The principal of these disturbing causes we found to consist in the extent to which the fats had been solidified prior to being melted, the rapidity with which the temperature of the water in which the tubes were immersed was raised, the weight of the bulb, the size of the tubes, the height of the column of fat, and the irregular manner in which the fats melted if the diameter of the tubes exceeded by more than a trifle that of the bulbs placed in them. If the tubes were large, the fats would melt in one part, chiefly near the outside, and be solid at another, so that the ascent of the bulb was in some cases unnaturally retarded thereby. To meet these sources of error, the fats were always solidified by immersion for an hour in water at a temperature of 13·3° C. The diameter of the tubes used was one-third of an inch, and the height four inches. These properly suspended, as shown in the diagram, were immersed in a large beaker of water. This itself was placed on an open water-bath, not a sand-bath, the temperature of the water being very gradually raised, and the thermometers used being of a limited scale and distinctly graduated in tenths of a degree centigrade (fig. 133).

In the observations the results of which we are now about to record, not merely was the fusing point of the fats taken as indicated by the rising of the bulb, but the point at which the fats became *clear* was also noted; this will also be found recorded, and it will be seen that there is a difference in most cases of about one degree between the two, the point of clearance being about one degree higher.

Points of Fusion and of Clearance of Butter.

	Point of Fusion.	Point of Clearance.
1	34·0	35·7
2	34·2	35·6
3	33·4	35·3
4	32·8	35·1
5	33·6	35·2
6	33·8	36·3
7	34·3	35·4
Mean	33·7	35·5

Points of Fusion and of Clearance of other Fats.

	Point of Fusion.	Point of Clearance.
Beef kidney	46·5	47·5
Beef caul	45·7	46·7
Mutton kidney	48·6	49·5
Mutton caul	46·0	47·0
Veal kidney	38·7	39·4
Veal caul	41·1	42·2
Lamb kidney	48·4	49·5
" "	51·6	52·9
Lamb caul	48·5	48·7
" "	46·2	47·5
Pig kidney	47·7	50·0
Pig caul	47·4	49·8
Lard { Home-rended	43·7	46·7
	42·6	45·4
Lard (Irish)	44·6	47·9
Beef dripping	43·5	45·8
" " (sirloin)	45·5	46·7
Mutton dripping (loin)	48·2	50·1
" " (leg)	42·3	43·3
Pig dripping	43·5	44·7

Points of Fusion and of Clearance of Mixtures.

The fusing point of the butter used for the mixtures in this and the following series of experiments was 34·3°.

I.—*Beef Kidney Series.*

Percentage of Foreign Fat.	Point of Fusion.	Point of Clearance.
10	35·9	37·1
20	37·8	40·0
30	39·8	41·7
40	41·4	43·0
50	42·7	44·1
60	44 0	45·0
70	45·0	46·2
80	45·6	47·0
90	46·1	47·4
100	46·5	47·5

II.—*Mutton Kidney Series.*

Percentage of Foreign Fat.	Point of Fusion.	Point of Clearance.
10	37·8	41·0
20	40·1	42·1
30	41·9	43·3
40	43·1	44·2
50	44·8	45·8
60	45·8	47·0
70	47·0	48·2
80	47·5	48·7
90	48·1	49·2
100	48·6	49·5

III.—*Pig Kidney Series.*

Percentage of Foreign Fat.	Point of Fusion.	Point of Clearance.
10	36·4	37·5
20	38·2	39·3
30	40·2	41·3
40	42·1	43·5
50	43·6	44·9
60	44·5	46·5
70	45·2	47·5
80	46·1	48·4
90	47·0	49·2
100	47·7	50·0

IV.—*Lamb Kidney Series.*

Percentage of Foreign Fat.	Point of Fusion.	Point of Clearance.
10	37·3	38·6
20	39·0	40·3
30	40·9	42·1
40	42·5	44·0
50	44·2	45·6
60	45·6	46·6
70	46·3	47·5
80	47·0	48·2
90	47·7	49·0
100	48·4	49·5

V.—*First Mutton Dripping Series.*

Percentage of Foreign Fat.	Point of Fusion.	Point of Clearance.
10	36·8	38·7
20	38·6	40·5
30	40·5	43·0
40	42·2	44·5
50	43·6	45·9
60	45·0	47·2
70	46·0	48·2
80	46·7	49·0
90	47·5	49·7
100	48·2	50·1

VI.—*Second Mutton Dripping Series.*

Percentage of Foreign Fat.	Point of Fusion.	Point of Clearance.
10	35·3	35·7
20	36·3	37·4
30	37·0	38·0
40	37·9	39·2
50	38·7	40·1
60	39·4	41·0
70	40·1	41·9
80	40·9	42·5
90	41·5	43·1
100	42·3	43·3

VII.—*Pork Dripping Series.*

Percentage of Foreign Fat.	Point of Fusion.	Point of Clearance.
10	35·0	36·0
20	35·9	36·8
30	37·3	38·0
40	38·0	39·1
50	39·0	40·1
60	39·9	41·0
70	40·7	42·0
80	41·6	42·7
90	42·5	43·8
100	43·5	44·7

VIII.—*Mixtures of Stearin and Olein.*

ercentage of Stearine.	Point of Fusion.	Point of Clearance.	Appearance.
10	47·5	50·2	Half liquid.
20	52·1	54·1	Buttery.
30	55·0	56·5	Lardaceous.
40	56·5	57·3	Consistence of beef fat.
50	57·5	58·3	Ditto of mutton fat.
60	58·4	59·1	Very hard.
70	59·0	59·7	ditto
80	59·7	60·4	ditto
90	60·4	61·3	ditto
100	61·5	62·6	ditto

From an examination of the preceding series of experiments it appears :—

1st. That the true melting point of butter ranges from 32·8 to 34·9; the mean of all the observations made being 33·7. The point of clearance of butter and, as will be seen, of the other fats also experimented upon, is always somewhat higher than the point of fusion, there being usually about 1° C. difference.

2nd. That the melting points of beef kidney fat, mutton kidney, lamb kidney and pig kidney fat, varied from 38·7 to 51·6, the mean being 46·90.

3rd. That the fusing points of beef caul fat, mutton caul, veal caul, lamb caul and pig caul fat, ranged from 41·1 to 48·5, the mean being 45·8.

4th. That the fusing point of lard varied from 42·6 to 44·6, the mean being 43·6.

5th. That the melting point of beef dripping, mutton dripping, and pig dripping varied from 42·3 to 48·2, the mean being 44·6; showing, on the whole, a much lower melting point than the fats themselves from which the drippings were derived.

It will thus be seen that there is a very wide difference between the melting points of butter and the whole of the fats above enumerated, so great indeed as to afford, with the more precise methods of procedure already described, a means of detecting the presence of any admixture of those fats with very great ease and absolute certainty.

Not only can the fact of the adulteration of butter with these and many other fats be thus determined, but the extent of admixture or adulteration may be approximately arrived at. Both these positions, and especially the former, are abundantly established by the observations above given.

The series of observations taken with mixtures of pure stearin and olein possess a different and special interest. It might have been presumed that they would have shown the relative proportions of the two glycerides in mixtures of different fusing points. In place of their doing so, however, the results arrived at, as will be seen above, are of a surprising and unexpected character. Thus, a mixture of olein with only 10 per cent. of stearin had a fusing point equal to that of pure beef or mutton fat. Now it is quite certain that these fats contain a very much larger proportion of stearin and palmitin than 10 per cent. The explanation of these anomalous results is probably to be found in the want of incorporation and real union between the olein and the stearin, so that the melting point of the stearin contained in the mixture approximates more or less closely to that of pure stearin. Still, it will be noticed that the melting point increases with the proportion of stearin present, not uniformly, but in a remarkably diminishing scale. The same want of uniformity in the ratio of increase of the melting point is also apparent on an examination of the other series of experiments with mixtures of different fats.

The results of these investigations appear to us practically to settle the question of the adulteration of butter with animal fats. Of course, it is quite possible to conceive of mixtures, specially prepared with a view to deceive, having the same fusing point as butter, but the further question to be asked is: Are such mixtures to be found and sold as butter? We have not to deal with chemical curiosities, but simply with those articles which are met with and sold under the name of and as butter.

We have, therefore, two methods, both of them reliable, and hence very valuable, for the detection of the adulteration of butter with animal fats, namely, the method of Messrs. Angell and Hehner, based upon the amount in butter and other fats of the fixed fatty acids, and that to the description of which this article is devoted, founded upon the different melting points of butter and all the fats ordinarily employed in its sophistication.

We will now proceed to describe the method of Messrs. Angell and Hehner, above referred to.

Messrs. Angell and Hehner first attempted to estimate directly the amount of the volatile acids contained in butter. They saponified a weighed quantity (usually 3 grammes) in a porcelain basin with caustic potash, frequently stirring with a glass rod. The clear butter soap was transferred to a flask or retort, and decomposed by means of dilute sulphuric acid. This mixture, which contained sulphate of potash, glycerin, and the volatile acids in solution, and the insoluble fatty acids, as stearic, palmitic, and oleic acids, floating on the top, was distilled, and the acidity of the distillate estimated by means of a soda solution of known strength. They found from 4·79 to 7·48 per cent. of the volatile acids in the distillate. The practical difficulties of this method, as the violent bumping of the boiling liquid and the impossibility to obtain a distillate perfectly free from acid, led Messrs Angell and Hehner to adopt a somewhat different and more indirect method of the estimation of the volatile acids. 'The volatile acids are, as we have mentioned, soluble in water, whilst palmitic, stearic, and oleic acids are insoluble. All animal fats, except butter, are mixtures of the glycerides of the three latter acids. Their equivalents being very high and nearly equal, the theory predicted that they would yield, on saponification and decomposition of the soap with dilute acid, nearly equal amounts of insoluble acids. Thus, pure palmitin would yield 95·28 per cent. of palmitic acid; pure stearin, 95·73 per cent. of stearic acid; and lastly, olein 95·70 per cent. of oleic acid. All animal fats, being mixtures of these three glycerides, should, therefore, yield a percentage of fatty acids ranging from 95·28 per cent. to 95·73 per cent., or say, on an average, about 95·5 per cent. To prove this theory by experiment, 3 grammes of mutton fat were saponified in a porcelain basin with a concentrated solution of potash. The saponification was very easy and quick, the liquid boiling quietly. Stirring with a glass rod assists very greatly. The water as it evaporates should be replaced by distilled water, so as to keep the liquid at about from 150 to 200 cc. A perfectly clear soap was obtained, which was decomposed with dilute hydrochloric acid. The fatty acids were fused in the liquid and collected on a previously dried and weighed filter. Before pouring the fatty acids on to the filter, the paper must be well moistened, or some of the fatty acids may pass through it. They were washed with boiling water, dried at 100° C., and weighed. Obtained 95·63 per cent., which figure agrees with the theory.

'Butter, which contains besides palmitic, stearic, and oleic, also volatile or soluble acids, should consequently give a lower amount of insoluble acids, these being diminished in the ratio to the quantity of the soluble acids. A weighed quantity of butter fat was saponified, exactly as was the mutton fat just mentioned. Obtained 86·07 per cent. of insoluble acids, or 9·5 per cent. less than any other fat could have given.' Messrs. Angell and Hehner made numerous estimations of the amount of insoluble fatty acids in butter and other fats, and found the former to yield from 85·40 to 86·20 per cent., whilst the latter gave invariably a quantity approaching very closely the theoretical amount—namely, 95·5 per cent. 'The average of the results is 85·85 per cent. of fixed acids. The difference between the quantity of fatty acids found in butter and that found in other fats is therefore on an average 9·65 per cent. Mixtures will yield quantities lying between 85·85 and 95·5 per cent. An adulteration of 100 per cent., *i.e.* the substitution of any foreign fat for butter, would give a difference of 9·65 per cent.; an adulteration of 10 per cent., therefore, would give a difference of 0·965 per cent. Each tenth of a percentage of fatty acids above the average figure would consequently be equal to 1·036 per cent. of adulteration; but it would be unjustifiable to declare a sample of butter to be adulterated because the fatty acids lie three or four tenths of a percentage above the average figure.'

Messrs. Angell and Hehner have proved the accuracy of their method by mixing butter and foreign fats in known proportions, and estimating the amount of fixed fatty acids. The mixtures yielded invariably quantities closely approximating to the calculated amounts.

Mr. Turner, public analyst of Portsmouth, has suggested the employment of alcohol with a view to hasten the saponification of the fat; this it effects by rendering it soluble and so facilitating and quickening the action of the alkali upon it, the saponification being thereby effected in a few minutes.

About 30 or 40 cc. of spirits of wine are added to the butter in a small glazed porcelain dish, and heated over the water-bath to near the boiling point. About 5 grammes of solid caustic potash are then added, and from time to time a few drops of water to facilitate its solution, the liquid being stirred all the time. In this manner the butter becomes rapidly saponified. The clear, yellowish solution is then freed from all alcohol over the water-bath, and the soap decomposed as already described. Care should be taken to remove all the alcohol, as a small quantity of the fatty acids might be held dissolved should any alcohol remain, and so lead to an erroneous result.

CHAPTER XX.

CHEESE AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any foreign substance, animal, vegetable, or mineral, excepting salt and annatto.

CHEESE consists chiefly of the curd of milk, ripened by keeping, with more or less of the butter and a variable quantity of water.

THE MANUFACTURE OF CHEESE.

The curd is usually precipitated from milk by means of a solution of rennet, which is prepared from the dried stomach of the calf and sometimes the pig.

It may be precipitated by means of acids, but these are rarely if ever employed in this country in the making of cheese; also by several other substances, as pure curd, old cheese, the natural fluids of the stomach, the first extract of malt and sour leaven. Professor Johnston particularly recommends trials to be made of the pure prepared curd. 'If,' he remarks, 'we are able to rescue the manufacture of rennet out of the mysterious and empirical hands of the skilled dairymaid, and by the use of a simple, abundant, easily prepared, and pure rennet, can command at once a ready coagulation of the milk, and a curd naturally sweet, or of a flavour which we had foreseen and commended, we should have made a considerable step towards the perfection of the art of cheese-making.'

Pure curd may be prepared in the following manner:—'Heat a quantity of milk which has stood for five or six hours; let it cool, and separate the cream completely. Add now to the milk a little vinegar, and heat it gently. The whole will coagulate, and the curd will separate. Pour off the whey, and wash the curd well by kneading it with repeated portions of water. When pressed and dried, the casein will be sufficiently pure for ordinary purposes. It may be made still more pure by dissolving it in a weak solution of carbonate of soda, allowing the solution to stand for twelve hours in a shallow vessel, separating any cream that may rise to the surface, again throwing down the curd by vinegar, washing it frequently, and occasionally boiling it with pure water. By repeating the process three or four times it may be obtained almost entirely free from the fatty and saline matters of the milk.'—'Transactions of the Highland Agricultural Society.'

The following is the *modus operandi* of rennet: it promotes the conversion of the sugar of milk into lactic acid, which, acting like other acids, occasions the precipitation of the curd, although, as already mentioned in the article on 'Milk,' rennet seems to possess the property of precipitating casein independent of the formation of any acid.

It has been objected to rennet that by it a readily fermentable and decomposable substance is introduced into the cheese, frequently causing it to pass into a state of decomposition.

It has been also objected that the stomachs from which it is prepared are often in a dirty and more or less decayed condition, and that the strength of the rennet made is very uncertain.

In order to obviate these latter objections the preparation of a solution of rennet, of standard and ascertained strength, has been suggested; salt, saltpetre, and other additions being made to ensure its preservation. Such a solution would appear to possess several advantages.

The proportions of casein and butter in cheese vary with the kind of milk from which the cheese is made; thus *skim milk* cheese is much poorer in butter than that made from *cream* or *whole milk.*

Cheshire cheese is of course made from whole milk; Stilton from cream; while cream cheese consists of the fresh curd of whole milk.

The salting of cheese may be effected in several ways; the salt may be added direct to the fresh curd, and this is the method usually practised in Scotland; or the newly made cheese may be immersed in a solution of brine; or the surface may be rubbed with dry salt—these methods are practised in Cheshire; or, lastly, the salt may be added to the milk previous to the precipitation of the curd. By this method the curd is very equally salted, but the quantity of salt required is very large, the greater part of it being retained in the whey.

The curd, before being compressed, is cut into small pieces so as to allow the whey to drain off; it is then placed, after being salted, in the moulds, a heavy weight being put upon it, but in some cases it is subjected to the progressive action of a screw press.

It is kept for some time in a cool place until it has undergone a kind of fermentation, whereby it acquires the peculiar flavour and the properties of cheese.

The changes which take place during the ripening process have not yet, we believe, been satisfactorily determined; but some interesting particulars will be found recorded in Pelouze and Frémy's 'Traité de Chimie'—their accuracy may in some particulars be doubted, and assuredly they need confirmation. It appears, however, certain that *leucin, butyric, caproic, caprylic, capric, lactic,* and *valerianic* acids, together with ammonia, are generated, the acids combining with the alkali to form salts. It is stated that as much as 21 per cent. of these ammonia salts have been found. The ammonia is doubtless derived from the decomposition of a portion of the casein.

THE COMPOSITION OF CHEESE.

The following analyses exhibit the percentage composition of most of the principal kinds of cheese met with in the market. The first series is recently made by the author, the second is by Payen :—

First Series.

	American.	Gloucester-shire.	Dutch.	Cheddar.	Stilton.	Cream Cheese.
Water . .	30·13	32·52	32·78	30·10	31·37	30·34
Fat . .	32·88	29·94	27·57	36·54	36·58	67·32
Casein . .	33·81	31·70	32·81	30·15	27·66	2·02
Ash . .	3·18	5·84	6·84	3·21	4·39	0·32
	100·00	100·00	100·00	100·00	100·00	100·00

Second Series.

	Chester.	Brie.	Neuf-châtel.	Mar-seilles.	Roque-fort.	Holland.	Gruyère.	Parme-san.
Water .	30·39	53·99	61·87	40·07	26·53	41·41	32·05	30·31
Fat .	25·41	24·83	18·74	28·73	32·31	25·06	28·40	21·68
Casein .	35·58	15·29	14·58	23·87	32·45	26·24	34·56	35·07
Ash .	4·78	5·63	4·25	5·93	4·45	6·25	4·79	7·09
	96·16	99·74	99·44	98·60	95·74	98·96	99·80	94·15

It thus appears that the composition of cheese is very variable, the variation affecting the whole of its constituents. Of course these differences are explained to a large extent by corresponding differences in the kind and mode of preparation of the cheese, but for cheeses of the same name and character greater uniformity will be found to exist.

Thus, for the purpose of determining whether a cheese be pure or not it must first be classified, and it must then be determined whether it is a cream, whole milk, or skim-milk cheese, and whether it is a hard cheese, or soft, like cream cheese. These natural differences in the composition of cheese render it somewhat difficult to deal with the question of its adulteration.

Johnston has analysed the ash of two samples of cheese: 1. of hand cheese; and 2, of Swiss cheese.

	Hand cheese.	Swiss cheese.
Potash	4·85	2·46
Soda	7·33	3·67
Lime	2·55	17·82
Magnesia	None.	0·81
Ferric oxide.	0·11	0·17
Carbonic acid	0·03	0·08
Phosphoric acid	13·68	20·45
Chloride of sodium	72·47	55·37
	101·02	100·83

It will be seen that the principal portion of the ash of cheese is made up of chloride of sodium, but it also contains notable quantities of phosphoric acid in combination with lime, potash, and soda, especially the former.

ANALYSIS OF CHEESE.

In making an analysis of cheese it is usually only necessary to determine the *water, fat, casein, ash*, and *salt*; in some cases, however, it may be desirable to ascertain the amount of *sugar* and *ammonia* present.

Estimation of water.—2 or 3 grammes of cheese should be cut into very fine slices, and dried on the water-bath in a platinum dish until they cease to lose weight.

Estimation of fat.—Next the fat may be estimated in the dried cheese, which should be first transferred to a small flask, by exhaustion with boiling ether. The quantity of fat may be ascertained either by the evaporation of the ethereal solution, or by noting the loss of weight of the dried cheese. It is necessary that the cheese should be thoroughly dry, or the ether will not act upon it. If in any case the cheese be not dry, it should be first moistened with a few drops of strong alcohol, after which the ether will dissolve the fat without difficulty.

Estimation of casein.—This is estimated with sufficient accuracy by igniting the residue insoluble in ether, and deducting from it the weight of the ash.

Another method would be by determining the amount of nitrogen by the ordinary combustion process.

Estimation of sugar.—The only cheese which contains any appreciable quantity of sugar is cream and other soft cheeses, and this may be extracted from the residue after the removal of the fat by means of ether, by treating first with strong alcohol and then with boiling water.

Estimation of ash.—This may be obtained either by incinerating a quantity of the cheese itself, or in the manner above referred to. If it be desired to estimate the amount of salt in the ash, the usual estimation of chlorine by means of a solution of nitrate of silver is to be made.

Estimation of ammonia.—About 50 grammes of cheese are thoroughly exhausted by means of repeated additions of boiling water. After filtration the solution, which contains, besides the sugar and chloride of sodium, the ammonia salts of the volatile acids, is transferred to a retort, and rendered alkaline by means of caustic potash. It is then distilled, and in the distillate the alkalinity is estimated by a standard solution of either hydrochloric or sulphuric acid.

The *volatile acids* may be obtained, together with hydrochloric acid, by boiling a portion of the watery solution obtained, as above described, with dilute sulphuric acid.

THE ADULTERATIONS OF CHEESE.

Colouring with annatto.—We have referred in the article on annatto to the practice of colouring cheese with *annatto*—a practice which we have shown to be useless, to entail some unnecessary expense, and, in consequence of the adulteration of annatto with injurious substances, to be attended in some cases with risk to health.

Other colouring matters are, however, sometimes employed for the same purpose as annatto; namely, *mangold flowers*, *saffron*, and the juice of red *carrots*; but most of the paler-coloured and all the high-coloured cheeses derive the whole of their colour from annatto. Stilton and Cheddar cheese are never coloured in any way.

It may be objected to the whole of these substances that their employment serves no useful purpose.

Flavouring with herbs.—Various articles are likewise added to cheese to flavour it, and to impart a green or diversified colour.

'In some dairies, the leaves of *sage*, *parsley*, and *other herbs*, are infused into cheese to give it a green colour. In other dairies part of the curd, when ready for the press, is exposed in a sieve to the air, in order that it may become oxygenated, and may render the cheese into which it is mixed with newly prepared curd, of a diversified colour, and of a disposition to run speedily into putridity. In a few dairies rapid putridity is induced by an intermixture of beaten potatoes. In Ross-shire, cheeses are for several days buried within seamark, in order that they may acquire a blue colour and a peculiar taste; and in France, a considerable quantity of cheese receives an offensive smell, resembling that of a pigstye, from the intermixture of fenugreek.—*Rural Cyclopædia.*

Adulteration with potatoes.—Cheese is made from *potatoes* in Thuringia and Saxony, in this manner:—'After having collected a quantity of potatoes of good quality, giving the preference to a large white kind, they are boiled in a cauldron, and after becoming cool, they are peeled and reduced to a pulp, either by means of a grater or mortar. To five pounds of this pulp, which ought to be as equal as possible, is added one pound of sour milk, and the necessary quantity of salt. The whole is kneaded together, and the mixture covered up and allowed to lie for three or four days according to the season. At the end of this time it is kneaded anew, and the cheeses are placed in little baskets, when the superfluous moisture escapes. They are then allowed to dry in the shade, and placed in layers in large vessels, where they must remain for fifteen days. The older these cheeses are, the more their quality improves. Three kinds of them are made. The first, which is the most common, is made according to the proportions just given; the second, with four parts of potatoes and two parts of curdled milk; the third, with two parts of potatoes and four parts of cow or ewe milk. These cheeses have this advantage over other kinds, that they do not engender worms, and keep fresh for a number of years, provided they are placed in a dry situation and in well-closed vessels.'—*Quarterly Journal of Agriculture.*

Adulteration with bean meal.—Cheeses are likewise made, in some cases, with *bean meal,* which contains a much larger proportion of nitrogen than the potato, and hence such cheeses will be much more nutritious than those made with potatoes.

Adulteration with Venetian red and reddle.—Venetian red and reddle are often employed to coat or colour the outer surface of many cheeses, especially Dutch cheese. This practice is objectionable in itself, but is particularly so in consequence of the Venetian red sometimes containing lead.

Sulphate of copper and arsenic.—The outer surface or rind of the cheese is sometimes washed over with a solution of these in order to protect the cheese from the attacks of the cheese mite and other parasitic productions. This practice is also very objectionable, since many persons not unfrequently eat the rind of the cheese.

Results of the Examination of Samples.

Twenty samples of cheese were subjected to analysis with the following results:—

All were artificially coloured, in most cases *with annatto.*

In none was *lead* present.

Several were coloured on the outside with *Venetian red* or *reddle* ground up into a paste with *grease.*

In none of the cheeses *was any substance,* either *organic or mineral, present,* added for the purpose of increasing the bulk and weight of the cheese.

These results are so far satisfactory, especially as respects lead.

It must not be concluded, however, from the results of these twenty examinations, that lead derived from the adulterated annatto employed to colour the cheese is never present. If it occur only in one sample out of a hundred, much mischief would result in some cases.

That it does sometimes occur in both annatto and cheese is proved by the evidence of Accum and Mitchell.

Accum, at page 276 of his 'Treatise,' affirms that several instances had come under his knowledge in which Gloucester cheese had been contaminated with red lead, and had produced serious consequences on being taken into the stomach. In some of these cases it was ascertained that the annatto which had been used to colour the cheese was itself coloured or adulterated with both vermilion and red lead.

Mitchell writes: 'I have only met with cheese that contained lead on one occasion, although it may be comparatively common.'

The practice of coating cheese with Venetian red and reddle is even more objectionable than the use of adulterated annatto, since, should this contain lead in any case, and since some persons are thoughtless enough to eat the rind, the quantity of that metal consumed would be more considerable.

Although cheese escapes for the most part the hands of the adulterator, it does not escape the attacks of fungi, animalcules, and insects; to these it is particularly prone, in consequence of its being so very rich in nitrogen.

The green and blue colours of mouldy cheese are due to the development of a fungus, *Aspergillus glaucus*, and the red colour or mould to another fungus, *Sporendomima casei*.

This mouldiness may be produced in comparatively new cheese by inoculation.

This is sometimes effected by inserting into the new cheese rolls of mouldy cheese, extracted by the scoop, into holes previously made by the same scoop.

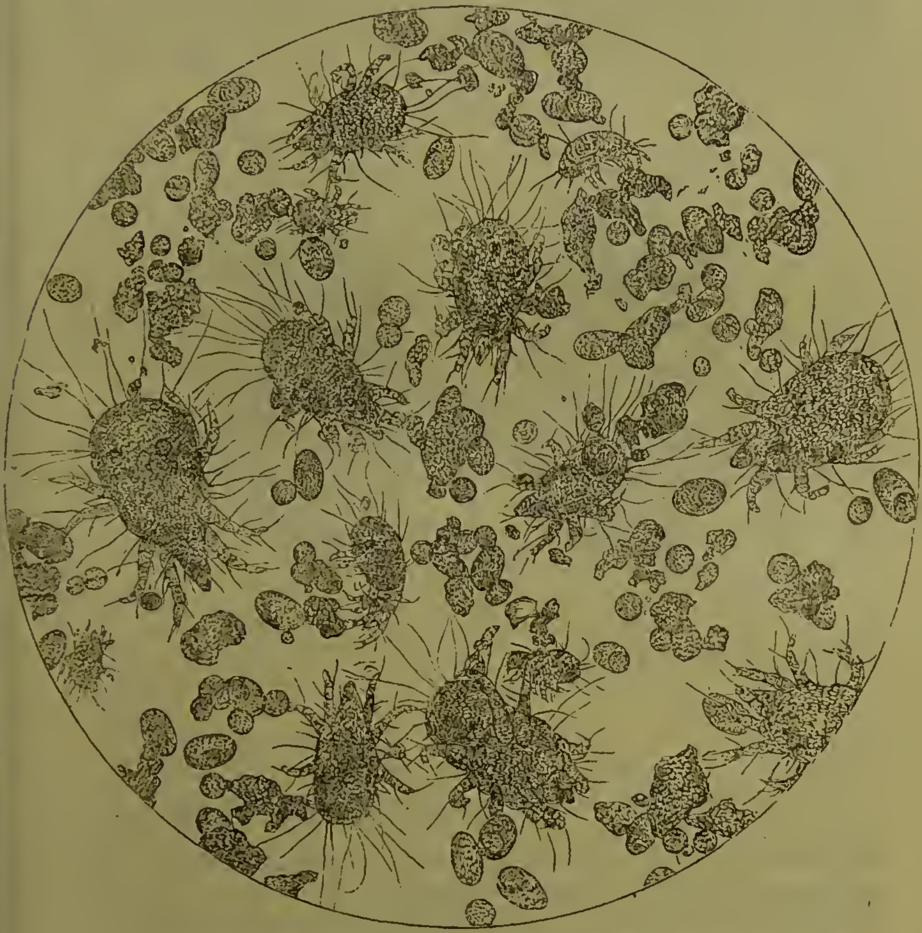
It is said that large pins are often thrust into cheeses, and allowed to remain in them for a considerable time in order to produce the mouldiness. This is a very objectionable proceeding, as in this case the colour is due partly to the formation of a salt of copper, and partly in some cases to the development of the fungus, which takes place in consequence of the admission of air into the interior of the cheese.

At a still further period of decay cheese is attacked by the well known cheese mite or acarus, *Acarus siro* of Linnæus, now called *Acarus domesticus*, and which is so small that it is scarcely perceptible without the aid of the microscope; *the dry and powdery parts of cheese consist almost entirely of these acari and their ova in different stages of growth* (fig. 134).

'We often wonder how the cheese mite is at hand to attack a cheese wherever deposited; but when we learn from Leewenhoek that one lived eleven weeks gummed on its back to the point of a needle without food, our wonder is diminished,' remark Kirby and Spence. Both these cheese maggots and mites, when numerous, destroy cheese rapidly, by crumbling it into small pieces, and by emitting a liquid substance, which causes the decayed parts to spread speedily. They may easily be killed, however, by exposure to strong heat, or by plunging the cheese in some liquid, such as whiskey, capable of destroying the larvæ without communicating any disagreeable flavour.

Besides the casualties from fermentation, cheese, when yet quite fresh, is subject to the attack of the cheese-fly (*Piophila casei*). The fly is ready to deposit its egg in the deepest crack it can find, by means of an extensile abdominal tube. The specific distinguishing characters of this insect, as drawn up by Mr. Duncan, are as follow:—'About two lines in length, the whole body of a greenish-black colour, smooth and shining; front of the head reddish-yellow, paler yellow on the under side. Thighs ochre-yellow at the base and apex; tibia deep ochre, the first and last pair black at the apex; anterior tarsi black, the others ochrey, with the two last joints and the claws black; wings clear and iridescent, slightly tinged with rust colour at the base, halteres ochrey.' —Kirby and Spence's *Introduction to Entomology*.

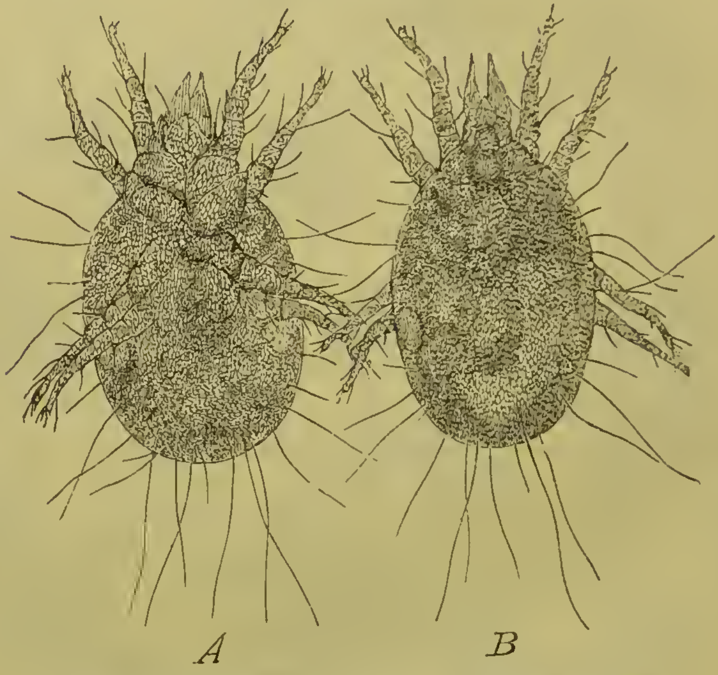
Fig. 134.



Dust of old Cheese, magnified about 40 diameters, composed entirely of *Acarus Siro* or *Cheese Mite*, in all conditions of development from the ova upwards.

The cheese maggots produced from this fly are as large as the fly, and commonly called *jumpers.* 'When this maggot prepares to leap, it first erects itself on its anus, and then bending itself into a circle, by bringing its head to its tail, it pushes forth its unguiform mandibles, and fixes them in two cavities in its anal tubercles. All being thus prepared, it next contracts its body into an oblong, so that the two halves are parallel to each other. This done, it lets go its hold with so violent a jerk, that the sound produced by its mandibles can be easily heard, and the leap takes place. Swammerdam saw one, whose length did not exceed the fourth part of an inch, jump in this manner out of a box six inches deep, which is as if a man six feet high should raise himself in the air by jumping 144 feet; he had seen others leap a great deal higher.'—*Book of the Farm.*

Fig. 135.



Anterior and posterior views of *Cheese Mite.* Magnified 40 diameters.

THE DETECTION OF THE ADULTERATIONS OF CHEESE.

The presence of *annatto* is sufficiently indicated by the colour, very obvious in most cheese, particularly when this is compared with an uncoloured cheese, such as Stilton.

The detection of potato.—Since the cells of potato contain a large quantity of starch, its presence, as well as that of any other starchy substance, will be at once ascertained by adding to a minute portion of the cheese a drop or so of a solution of iodine. The cells of potato are characterised by their large size and rounded form (fig. 108). They would be best seen after the extraction of the fat by means of ether. Of course potatoes would only be employed in the adulteration of cheese after they had been cooked and mashed.

The quantity of potato present must be estimated from the amount of starch, obtained as glucose in the usual manner by boiling with dilute sulphuric acid; 100 parts of potato contain about 23 parts of starch.

The detection of bean meal.—For the detection and estimation of this we must proceed exactly as in the case of the mashed potato. The characters of the starch corpuscles and cellulose, as revealed by the microscope, and which have already been described, will serve sufficiently for its identification.

The detection of animal fats.—It is quite within the limits of probability that in some cases *animal fat* may be employed in the manufacture and adulteration of cheese. Such an adulteration admits of detection in the following manner:—About 100 grammes of the cheese should be heated in the water-bath, when the fat will separate and may easily be poured off. This should be placed in a test-tube, and its fusing point taken in the manner already fully described in the article on 'Butter,' the fusing point proving whether there has been any admixture of animal fat or not.

On the detection of Venetian red.—When the cheese is artificially coated or coloured, the coating should be separately examined for iron and lead.

The general method of proceeding is as follows:—About four or five grammes of the rind of the cheese should be incinerated in a porcelain basin, and the ash tested for lead and iron as directed elsewhere in this work.

The detection of sulphate of copper and arsenic.—A portion of the rind of the cheese should be incinerated, the ash treated with nitric acid, and the solution rendered alkaline by ammonia, when the characteristic blue colour of *ammonio-cupric sulphate* will appear; or if the quantity of copper be very small, the ammoniacal solution should be acidulated with acetic acid and tested with a solution of ferrocyanide of potassium, which will produce a reddish-brown coloration or precipitate of *ferrocyanide of copper*.

The detection of the *arsenic* is a more complicated and difficult operation. Upon the rind of the cheese pure strong hydrochloric acid is poured, and the mixture heated in the water-bath. Chlorate of potash is then to be added in small quantities at a time. The chlorine thus evolved destroys most of the organic matter, with the exception of the fat. As soon as the liquid becomes clear it is allowed to cool, and is then filtered, whereby the fat is separated. The solution is heated on the water bath until all smell of chlorine has disappeared. A current of pure sulphuretted hydrogen is now passed through the liquid for at least twelve hours, it being heated to about 70° C. at the same time. The arsenic, if any be present, is thereby precipitated in the form of sulphide of arsenic, mixed with a large quantity of sulphur and organic matter. The precipitate is collected on a filter, washed with water containing some sulphuretted hydrogen in solution, and dried. The filter with the precipitate is then drenched first with pure strong nitric acid and then with sulphuric acid, and heated on the sand-bath in a small porcelain basin until fumes of sulphuric acid begin to escape. The mass is then allowed to cool, and the arsenic extracted with water acidulated with pure hydrochloric acid. Sulphuretted hydrogen is again passed through the liquid, whereby the arsenic, together with any heavy metal which may be present, is thrown down in the form of sulphides, this time in a state of purity. If the precipitate be of a pure yellow colour and soluble in a solution of carbonate of ammonia, there cannot be any doubt of the presence of arsenic; but if it be black, as would be the case if copper be present, it must be washed with water containing sulphuretted hydrogen and then extracted with yellow sulphide of ammonium. The arsenic passes into solution, whilst the sulphide of copper remains undissolved. The liquid is filtered and the filtrate is acidulated with hydrochloric acid, whereby the sulphide of arsenic is again rendered insoluble. The precipitate of sulphide of arsenic is collected on a filter, dissolved in ammonia, and the solution again precipitated with hydrochloric acid. Thus the sulphide of arsenic is obtained in a pure state.

For its further identification it may be mixed with dry cyanide of potassium and carbonate of soda, and heated in a slow current of carbonic acid, when pure arsenic will sublime.

If the metallic arsenic thus obtained be heated with access of air by breaking off the closed end of the tube, arsenious acid will be formed, which sublimes and crystallises in the cool part of the tube in the form of well-defined octahedral crystals, plainly visible with a lens or a low power of the microscope.

CHAPTER XXI.

LARD AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any foreign substance, whether animal, vegetable, or mineral; as dripping, farina or flour, alum, &c., excepting water and salt, which should not exceed two per cent. respectively.

Lard is the fat of the pig freed from the tissues in which the fatty matter is contained. The process by which this is separated from the vesicular, fibrous, and vascular tissues in which it is either enclosed, or by which it is surrounded, is termed *lard rending.*

The pieces of fat to be converted into lard are sometimes salted a little, the better to ensure their preservation, and are stored in barrels. The fat which immediately surrounds the kidneys yields the best and purest lard; this is owing to its being in a freer state, that is, it is less highly organised. The process is as follows:—The pieces of fat are scored or sliced into lesser portions of an inch or so in diameter; they are placed, either with or without the addition of a little water, in cauldrons, which are usually of iron. The mode of applying heat to the flare varies in different cases. When lard is made on a small scale the flame is often applied directly to the containing vessel; sometimes the flare is melted in a water-bath, but usually the heating medium is steam, which is contained in the interval between the inner and outer vessel or pan; occasionally a jet of steam is thrown directly upon the flare contained in the copper. The oily part of the fat melts out and floats on the surface, the animal matter and tissues either forming a scum, which is skimmed from time to time, or sinking as a deposit. As the oil has no affinity for either water or salt, it does not take up any of the water which may be present with it in the copper, while the salt used to preserve the fat is partly held in solution and partly falls as a sediment. The oil, whilst still warm and fluid, is turned out of the copper through a tap, and is received either into bladders or casks termed kegs, and hence the division of lard into *bladder lard* and *keg lard.* It is usually the best description of lard only which is stored in bladders, keg lard being for the most part of inferior quality. Good and pure lard should be entirely free from either taste or smell; it should be firm and white, and when melted be almost as clear and transparent as water; subjected to a temperature of about 100° C., it should liquefy without ebullition, thus showing the absence of water, and should not throw down a particle of deposit. Inferior or adulterated lards possess characters and properties almost the reverse of these. The melting point of lard, as determined by the author with considerable care, ranges from 42·6 to 44·6, the mean of several observations being 43·6° C. According to Braconnet its composition is as follows:—Stearin and margarin, 38; olein, 62.

Our supplies of lard are derived principally from Ireland, part also comes from America and Hamburg, while London and our chief provincial cities possess lard manufactories.

THE ADULTERATIONS OF LARD.

We have long been aware that lard, like nearly every other article of consumption, is liable to adulteration: indeed, the fact that it is so is very generally known to dealers, as also the nature of the principal adulterations practised.

The chief adulterations of lard resemble those of butter, and consist in the incorporation with it of *water* and *starch*. Sometimes the water only or the starch only is had recourse to; in others both these adulterations are practised on the same lard.

We have ourselves met with many samples of lard adulterated with *potato flour*; but one of the earliest to draw attention to the subject was Mr. George Whipple, in a communication which he brought before the Pharmaceutical Society, and which was noticed in its Journal for January 1853; in this he states that he had detected large quantities of some farinaceous substance in lard.

'This adulteration,' writes Mr. Whipple, 'was discovered in the different varieties of lard—from the finest bladder to the common firkin lard. In an examination of the contents of two firkins, weighing 105½ lbs., a quantity of farinaceous substance, amounting to 22¼ lbs., was separated. The contents of another firkin, weighing 43¾ lbs., yielded 12¾ lbs. of a similar substance.'

In the next number of the same journal, Mr. Calvert, of Manchester, published some further observations on the adulteration of American lard. He writes:—'During the numerous analyses I made some three years since of various articles of food employed in public establishments, I analysed several samples of American lard, and therefore may add to the fact already mentioned by Mr. George Whipple in your last number, that I found them to contain, in addition to starch, from 10 to 12 per cent. of water, and from 2 to 3 per cent. of alum, and about 1 per cent. of quicklime.

'A few months ago I was able to ascertain that the operation is conducted in the following manner:—

'The fatty matters, such as they arrive from America, are melted with a little water in false-bottomed copper pans, through which circulates a current of steam. The dirt and other heterogeneous matters fall to the bottom of the pans, and the clear grease is allowed to run into a wooden vessel, when it is stirred in contact with cold water; it is then put under revolving wheels with a thick paste made of potato starch, mixed with a little potash alum and quicklime, which appears to facilitate the taking up of the water and starch by the fatty matter.

'The cause of the American lard appearing so white is, no doubt, the division of the fatty matter through the interposition of the starch, water, and alumina.

'The quantity of alum should be such that a small excess should remain to prevent the starch from becoming mildewed; and I believe that the manufacturer also adds it for the purpose of communicating to the lard the property of facilitating the raising and increasing the whiteness of the confectioners' paste, in which it is largely employed.'

It should be understood that American lard, as brought to this country, is not in general adulterated. The adulteration usually takes place subsequent to its arrival, and is the work of some of our own manufacturers. The reason why American lard is so frequently selected for adulteration is, that it is of inferior quality and value, and so soft as to be almost fluid, some process of consolidation being indispensable before it can be employed as lard.

From information received from a respectable lard-render, it appears that the addition of a small quantity of *mutton suet* to lard is very common. It is used more particularly in warm weather, and with soft lards, especially American lard, which differs from ordinary lard, in that it consists of the entire fat of the pig melted down, and not, as is the case with the best English lard, of the fat only which surrounds the kidneys. Mutton suet, being a hard and firm fat, imparts to soft lards, even when added in very small quantities, the consistence and solidity requisite.

It appears, therefore, that water, starch, alum, and caustic lime have all been ascertained to be employed in the adulteration of lard. To these substances we may add the following:—Carbonate of soda, carbonate of potash, and salt. The whole of the above adulterations may be readily discovered.

Results of the Examination of Samples.

The results of the examination of upwards of 100 samples of lard were as follow:—

1. That lard is not unfrequently *extensively adulterated*, the ingredients employed being *water* and *potato flour*, as well as certain saline substances, as *salt*, *potash alum*, *carbonates of potash* and of *soda*, and *caustic lime*, these being intended either to cause the lard to hold water, or to improve its consistence and colour.
2. That the description of lard most liable to adulteration is *keg lard*, and of this, particularly that which is manufactured in England; Irish keg lard being but rarely adulterated.

3. That of upwards of *one hundred* samples of lard submitted to examination, and procured chiefly from retail dealers, *seven* were found to be adulterated with *potato starch.*

The adulteration of lard prevails not only in certain localities, but also chiefly at certain times—that is, whenever a sufficient supply of inferior lard, suitable for mixing, can be procured; for it is said not to answer to adulterate a lard of good quality, which commands a high price, and which is spoiled by being tampered with.

It will be readily perceived that the qualities of a lard thus adulterated must be seriously impaired for almost every purpose for which it is employed: thus, of course, it would not be nearly so economical for culinary purposes. The use of such lard in machinery might, in some cases, produce serious consequences by impeding its action. Lastly, the activity of all the ointments of the Pharmacopœia, made with such a lard, would be much injured, especially the simple and compound iodine ointments, which, if starch were present, would, to the astonishment of the dispenser, turn blue, or almost black, in the act of incorporation.

The Detection of the Adulterations of Lard.

The first thing to be done in order to ascertain whether a lard be genuine or adulterated, is to melt it at about a temperature of 100° C. If it fuse without ebullition or without the occurrence of a deposit, we may safely conclude that the sample is genuine; but if ebullition take place, or a sediment is thrown down, the lard is unquestionably adulterated.

Detection of water.—The adulteration of water, and the quantity present, may be thus determined:—A known weight of lard, say 2 grammes, is to be exposed to heat until the lard ceases to lose weight; the loss indicates the quantity of water.

Detection of starch.—The presence of starch may be discovered by thoroughly mixing a drop of a tincture of iodine with a few grains of the lard, placed upon a slip of glass; the lard will change colour, and become deep blue, or almost black. If now a little of this be viewed under the microscope, the starch corpuscles will themselves be seen coloured by the iodine.

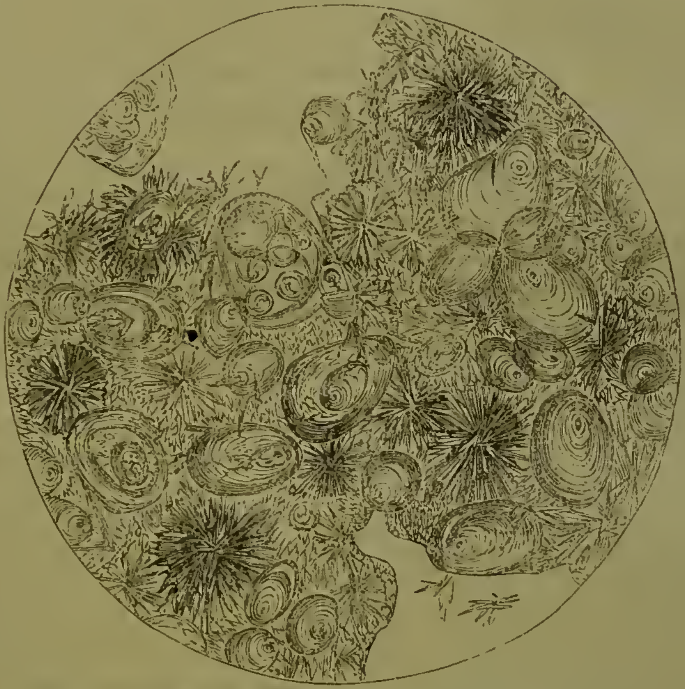
To determine the kind of starch contained in any sample, we must use the microscope. A minute piece of the lard should be placed on a glass slide, previously thoroughly warmed; the moment the lard is melted it must be viewed by the object glass, when the starch corpuscles will be distinguished standing out as clearly as though they were in water.

Another way in which the starch corpuscles may be well seen by the microscope, is to spread out by gentle pressure, between two pieces of glass, a very thin stratum of the lard, or the fatty matter may be first removed by means of ether and the residue examined.

For the estimation of the quantity of starch present, the lard should be melted, and, while still warm, successive quantities of ether should be poured upon it until all the fat is removed. The residue should then be dried in the water-bath, weighed, incinerated, and the weight of the ash, if any, subtracted.

Determination of the saline matter.—For the determination of the saline matter, 10 grammes of the lard should be incinerated, the ash weighed and tested in the usual manner by the processes for the estimation of chlorine and sulphuric acid given under 'Tea,' and of lime given in the same article. The alumina may be easily estimated by dissolving the ash in hydrochloric acid and precipitating with ammonia, which will throw down pure alumina, which is separated by filtration, washed, incinerated, and weighed, as described in the article on 'Bread.'

Fig. 136.



LARD, adulterated with *Potato* starch. Magnified 240 diameters.

The carbonates of soda or potash are detected by the alkaline reaction, and the effervescence of the ash with acids. They may be estimated by extraction of the ash with water, and taking the alkalinity by means of a standard solution of sulphuric acid.

CHAPTER XXII.

ISINGLASS AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Admixture with gelatin, or substitution thereof for isinglass.

Isinglass is the air bag, or swimming bladder, sometimes called the sound, of various fish, chiefly of the sturgeon tribe, and belonging to the genus *Acipenser*.

This bag is a membrane filled with air, situated near the spine, above the centre of gravity. In most fish it communicates with the œsophagus, or stomach, by a duct, which is known as the *ductus pneumaticus*; in others, the duct is imperforate; occasionally there are two sacs, one anterior to the other, and communicating by a short tube.

The air bag is made up of an external or peritoneal covering; a middle, fibrous, and in some cases muscular coat; and an internal, highly vascular membrane.

The following are the principal species of fish from which Russian isinglass is derived:—*Acipenser Huso* or the *Beluga*, *A. Gouldenstadtii* or the *Osseter*, *A. Ruthenus* or the *Sterlet*, *A. Stellatus* or the *Sewruga*, *Silurus Glanis*, and *Siprinus Carpio*.

In addition to the above, isinglass is obtained in different parts of the world from several other kinds of fish. In New York, from the *Labrus Squeteague*, of Mitchell. In New England it is procured from the intestines of *Morrhua vulgaris*, or the common cod, this form being denominated *ribbon isinglass*. In the Brazils, it is obtained from a large fish, probably a species of *Silurus*; and in Iceland, from the *Cod* and *Lota Moloa* or *Ling*.

For an account of the fisheries and the mode of preparation or drying of the swimming bladder, the reader is referred to the author's work, 'Food and its Adulterations.'

The principal kinds of isinglass are *leaf, short staple, long staple*, and *book* isinglass.

Samovey short staple and book isinglasses are usually of inferior quality.

In addition to the isinglass imported from Russia, a vast quantity is annually received from the Brazils, and the East and West Indies. It is, however, greatly inferior to the descriptions we have noticed.

Indeed, *Brazilian isinglass* is only fit for fining purposes, and for such it is almost wholly bought up by the proprietors of large brewing establishments, who consume nearly the entire quantity imported.

Manufacture of Isinglass.

On the arrival of the isinglass in this country, the best kinds are submitted to a course of preparation before they are ready for consumption.

The Beluga leaf is closely examined, and all discoloured parts cut away; the cuttings, and other pieces not deemed good enough for the *best*, are placed aside as *seconds* or *thirds*. These, in some cases, are used for fining the better descriptions of ales, but more generally for wines, liqueurs, &c. It is also rolled and cut into shreds for domestic purposes, where colour is not an immediate object.

Purse isinglass is mostly sold to the brewers, who consume a vast quantity in the fining of their several beverages.

Long and short staple isinglass is extensively demanded by cider-makers, confectioners, and others, to whom it is sold in the same state as imported into this country.

Leaf isinglass taken from the Beluga, after having been picked from all impure or discoloured pieces, constitutes the very best article, either for dietetic use, or for the higher class of clarifying purposes. This description of isinglass has to undergo a process of manufacture before it is ready for use. What are termed perfect specimen leaves are nearly round, the bladder having been opened longitudinally, about two feet in circumference, and weigh from eight to sixteen ounces, according to the thickness of the sound. It is not uncommon, however, to meet with heavier samples, some having been known to reach four pounds.

A steam-engine of some eight or ten horse-power is generally used under the present method of preparing isinglass, the adjunct machinery consisting of a series of powerful rollers, arranged in pairs in a manner resembling those used for expressing the juice from the sugar-cane. The rollers when in motion are fed with leaf isinglass as fast as possible, which, in passing between the two rollers, becomes amalgamated and spread out, and is expelled from the opposite side of the rollers in one continuous sheet. The isinglass thus rolled is called 'ribbon,' but it is not yet ready for the process of cutting.

The sheet or 'ribbon' is probably a sixth, eighth, or tenth part of an inch in thickness, and as it is necessary to reduce it until it is as thin as writing paper, it is passed through rollers more closely set, until, as the thickness diminishes, the desired result is obtained; the width of the 'ribbon,' of course, increasing.

It is to be remarked that in rolling, the ribbon, being confined to the width of the rollers, generally about two feet, increases only lengthwise, and, when completed, can be folded or rolled up in the same manner as a length of common linen.

After a brief delay, for the purpose of drying, the next and last process of cutting is effected. By the introduction of modern machinery, this part of the preparation of isinglass is performed with surprising celerity, and the material is cut into very fine shreds.

The cutting machine is a cylinder with some five or six keen-edged blades fixed in a tangential direction to the cylinder. The same engine which serves to roll out the isinglass, as already described, suffices to turn this little machine at the rate of some 800 or 1,000 revolutions per minute; taking a low estimate, we will suppose it turns 800 times. On examining the cylinder we find five or six blades set in it, and as each of these knives severs a shred from the width of the 'ribbon,' while the cutting process is going on, it follows that four or five thousand shreds are cut in the short space of one minute.

Such is the plain and simple method of preparing cut isinglass.

There are, however, many consumers who still prefer the old-fashioned style of hand-cut isinglass. In this case, the thin leaf is pulled to pieces with the fingers or divided into strips with scissors, a work mostly performed by women.

The shreds of isinglass, softened in cold water and examined under the microscope, are seen to possess a fibrous structure, a few vessels, granular cells, and nuclei being scattered here and there; it is, in fact, an organised substance (fig. 137).

THE ADULTERATIONS OF ISINGLASS.

The principal adulteration of isinglass is with gelatin, an article in every respect inferior to isinglass.

Usually shreds of gelatin are mixed with those of isinglass. Occasionally the gelatin is incorporated with the isinglass while it is in sheets.

Most frequently, however, gelatin is substituted for isinglass. The best isinglass, of course, is Russian; this is often deteriorated by admixture with a very inferior article, termed *Brazilian isinglass*: in other cases, this is substituted for the better and more valuable description of isinglass.

Results of the Examination of Samples.

Of *twenty-eight* samples of isinglass subjected to examination, ten, or more than one-third, of the samples consisted entirely of GELATIN.

THE DETECTION OF THE ADULTERATIONS OF ISINGLASS.

Between isinglass and gelatin several well-marked distinctions exist; some of these are sufficiently simple to enable the ordinary observer himself to distinguish the one article from the other.

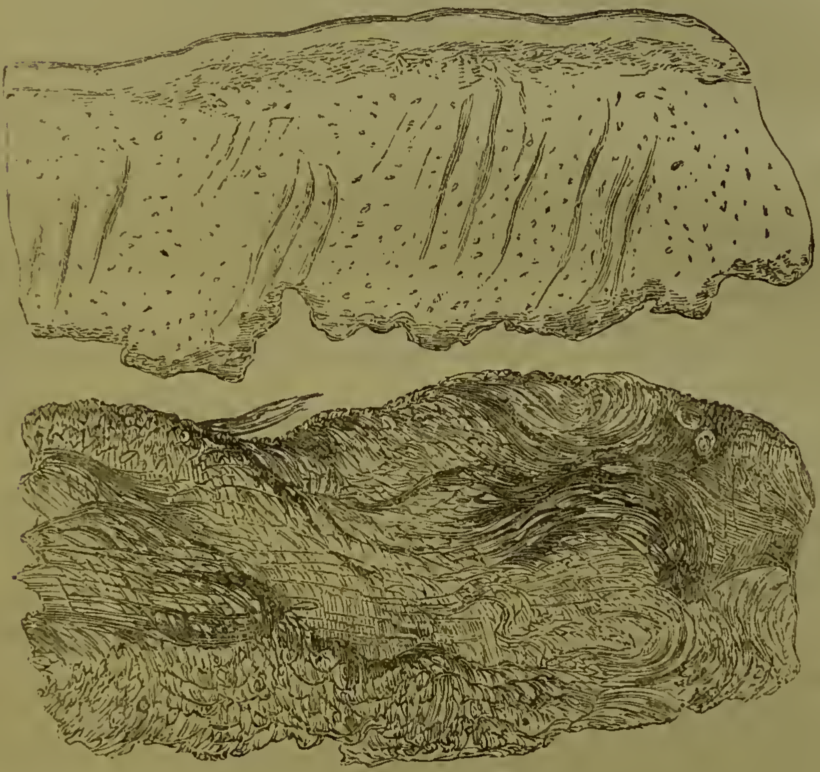
All that is necessary to effect the discrimination is to spread a few of the filaments out on a slip of glass, to moisten them with water, and after the lapse of a few minutes to note well the appearances presented by them.

Isinglass and gelatin differ, especially in the following characters :—

The shreds of *isinglass*, when immersed in cold water, become white, opaque, soft, and swollen.

The swelling is equal in all directions, so that, when viewed with a low power of the microscope, the shreds appear more or less quadrangular.

Fig. 137.



Sections of shreds of Gelatin and Isinglass. Upper figure, *Gelatin* ; lower, *Isinglass*. Magnified 75 diameters.

In boiling water they dissolve nearly without residue.

The smell of the dissolved isinglass, when hot, is somewhat fishy, but not unpleasant.

The moistened shreds, or the solution, exhibit to test paper a neutral, or faintly alkaline, and rarely a slightly acid reaction.

Under the microscope the filaments exhibit a well-marked fibrous structure.

In acetic acid they swell up, and become soft and jelly-like, the greater part of the structure being lost.

Lastly, 'The ash which results from the incineration of good Russian isinglass is of a *deep red* colour; it contains but a small portion of carbonate of lime, and never amounts to more than nine per cent. of the isinglass used.'[1]

The shreds of *gelatin*, on the contrary, when placed in cold water, swell up, acquire increased transparency, and become translucent and glass-like.

The form which the shreds take in swelling is peculiar: they do not, like those of isinglass, swell equally and remain quadrilateral, but become expanded, flat, and ribbon-like, the broad surfaces corresponding to the incised margins.

The dry shreds on the uncut surfaces frequently present a peculiar, shining lustre, not unlike that of tinsel.

In boiling water they do not entirely dissolve, but in most cases a copious deposit falls to the bottom of the glass.

The smell of the hot infusion is like that of glue, and therefore disagreeable.

The moistened filaments, or the solution of gelatin, usually exhibit a strong acid reaction: this in some cases is due to the substances used in bleaching it.

They show no structure under the microscope, but only the marks of the instrument employed in cutting them.

Immersion in dilute acetic acid hardens gelatin.

Lastly, the ash is different from that of isinglass in amount, colour, and composition. '100 grains of gelatin give from 2·3 to 2·6 grains of ash, which is *white*, contains much carbonate of lime, with some chlorides and sulphates.'—*Letheby*.

It is therefore very easy to distinguish between isinglass and gelatin, even when the shreds of the two articles are mixed together in the same parcel.

The discrimination is, however, much more difficult when they are both incorporated in the same shreds or strips; nevertheless, by means of the microscope, this adulteration, first described by Dr. Redwood, may frequently be discovered.

If, on examination with that instrument, the shreds, after immersion in cold water for a few minutes, exhibit a thick border of a clear and structureless substance, there is no doubt but that the shreds are coated with gelatin.

Some of the better kinds of Brazilian isinglass are manufactured in the same way as Russian, and sold at a cheaper rate. No doubt, in some instances, this is mixed with or sold as the best, and it has been ascertained that acids and other chemicals have been used to improve its colour; but the test of good isinglass is in the jelly made therefrom.

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[1] 'Pharmaceutical Journal,' vol. x. p. 127.

The jelly made from Russian isinglass dissolves readily, furnishes scarcely any sediment, and is remarkably firm, pure, and translucent.

On the other hand, Brazilian isinglass makes a far inferior jelly, with these remarkable differences: that whilst Russian isinglass is firm and free from deposit, Brazilian isinglass leaves a deposit of insoluble matter amounting to 20 or 30 per cent., is less readily dissolved, and the jelly is opalescent and milky.

On making *blanc-mange* with the purest Russian isinglass, milk is needed to impart the snow-white colour of that jelly; but in the case of Brazilian isinglass hot water alone will render it nearly of that colour. It is almost needless to add that the *blanc-mange* is much inferior in quality, and the large percentage of insoluble matter renders the jelly proportionately weak.

The quality of any isinglass may easily be tested by dissolving a small portion in a glass vessel, with about a tablespoonful of boiling water. The best Russian isinglass will instantly dissolve, and scarcely a particle of sediment remain; the soluble matter in this article being, according to the best authorities, ninety-eight grains in every hundred.

The same test applied to Brazilian isinglass will extract the gelatin, but the shreds, from their fibrous character, do not entirely dissolve; they turn white and retain their form, unless disturbed, in which case they break up, and form a deposit at the bottom of the vessel.

If Russian isinglass be adulterated with Brazilian, the admixture may easily be detected by the insoluble shreds, or white deposit, which is sure to appear in proportion to the amount of Brazilian isinglass that may be introduced. The smell of the latter also is strong, far from pleasant, and forms a great contrast with the faint, inoffensive, seaweed-like odour of Russian isinglass.

CHAPTER XXIII.

GELATIN AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any addition of salt or sugar.

PREPARATION OF GELATIN.

We have been at some pains to procure the following information respecting the manufacture of gelatin.

Ordinary gelatins are made from those pieces of skins which are cut off by the tanner as unfit for making leather, in consequence of thickness. The best description is prepared from the skins of calves' heads; these are separated from the whole skins after they have passed through the process of liming, to remove the hair from them.

The skins are next well washed to get rid of the lime, and all the pieces of flesh and fat are carefully cut out; some manufacturers soak them for a short time in a dilute solution of muriatic acid, to remove any remaining portion of lime; but this practice is both injurious and unprofitable. The acid forms with the lime chloride of calcium, which, if it is not carefully removed by washing, is boiled up with the skins, and, being soluble, remains in the gelatin; a portion of the skins is also dissolved by the acid, and is thrown away in the water employed in washing them, which thus occasions a loss in weight.

In some cases the skins are boiled whole, in others they are cut into small pieces, or even reduced to a pulp by a machine especially constructed for the purpose.

If the skins are cut into fine pieces instead of being put into the boiler whole, the gelatin will be better, that is, it will be of a lighter colour; and the process is more economical, as one-half the time will be saved in the boiling, and much less heat and fuel required. As the gelatin is darkened by prolonged boiling, the reduction of the skins to a pulp is a point of very great importance in the manufacture of gelatin—so much so, that Mr. Swinburne has obtained a patent for this method of preparation.

The skins are boiled with water, in the proportion of about one gallon of water to seven pounds of skin; a small quantity of common salt is added to preserve the gelatin. After it has boiled for about twelve hours, it is strained and clarified with white of eggs, and then run upon glass plates; as soon as it is solid, it is cut into slices and laid upon nets to dry, in a room heated to a temperature of about 80°. If the room is not heated, the surface of the gelatin becomes covered with small air-bubbles; when the gelatin is dry it is cut by a machine in the same manner as isinglass.

The size of the glass plates varies according to the fancy of the manufacturer. The ordinary size is fifteen by eighteen inches, but in some cases they are three feet square; the plates or slices of gelatin are generally about fifteen inches long by three wide.

Though the skin of the head of the calf only is used for making gelatin, the whole of the skins both of the calf and ox are perfectly adapted for the purpose, but are not used, as they are much more valuable for conversion into leather.

In some cases, especially in warm weather, the skins used are somewhat decomposed, but this is not generally the case. This condition, although removed to some extent by repeated washings, cannot be entirely remedied; hence gelatin made from such damaged skins will always retain a smell and taste more or less disagreeable.

French gelatin is usually much whiter than English; this is owing principally to the calves being killed in France much younger than in this country.

Gelatin is likewise prepared from the bones of the ox and the sheep. It is obtained by boiling bones in water under pressure. It is more readily procured by employing bones which have been previously digested in hydrochloric acid to extract the phosphate of lime. 'In this way a nutritious soup is prepared in Paris for the hospitals and other pauper habitations. Gelatin has been extracted from antediluvian bones. A soup was prepared from the bones of the great mastodon by a préfet of one of the departments of France.'—*Pereira.*

In the 'London Journal of Arts and Sciences,' a publication which contains the specification of new patented inventions, we find the following description of a patent granted to George Philbrick Swinburne, of Pimlico:—

'The patentee commences his specification by stating that heretofore, in manufacturing gelatin, it has been usual (with one exception) to act on large pieces of hides or skins, and to employ acids and alkalies, together with mechanical and other processes, which occupy considerable time, and are likewise costly; and in the excepted case above referred to it has been the practice to reduce the pieces of hide into the state of pulp in a paper-machine, and then to employ blood to purify the product obtained.

'This invention consists in the following more simple mode of manufacturing gelatin:—The patentee takes hides or skins, or parts thereof, as fresh and as sweet as possible, and free from hair, and he reduces the whole into shavings or thin slices or films, by any suitable instrument; he soaks the shavings or films for about five or six hours in cold water, and then changes the same; he repeats such changing of the water two or three times each day, until no smell or taste is to be detected, either in the water or in the shavings, and then he removes the shavings from the water. If this product is intended for soup, it is dried on nets, and is then ready for use. If gelatin is to be extracted, the shavings, after the above soaking, are put into a suitable vessel, with a quantity of water, sufficient to cover them when pressed down, and they are subjected to a heat not exceeding boiling water. When dissolved the gelatin is to be strained through linen or other fabric, subjected to slight pressure with the hands or otherwise, or the solution may be permitted to run off from the vessel without straining, by which means much of the gelatin will be separated from the fibrous matters. The product of gelatin thus obtained is run in thin films on to a smooth surface of slate, or other suitable material, to set; it is then removed on to nets to dry, and when dry it is cut up with an isinglass cutter or other suitable apparatus. The residue, dried or not, may be used for thickening soup, and other culinary purposes.'

'Another manufacture of gelatinous substances is produced by the following process, from cod sounds, or other fishy matters capable of yielding gelatin;—These matters are reduced to shavings or thin films, soaked in water, subjected to the action of heat, and the gelatin strained or run off as above described. The patentee obtained a first, second, and third product of gelatin, which he forms into sheets, and when dry cuts up the same with an isinglass cutter. This manufacture of gelatin will be found highly useful as a cheap substitute for isinglass for clarifying liquids.'

Inferior gelatin is used in large quantities by paper-makers, straw hat and silk manufacturers; but these parties generally purchase the skins, and prepare the gelatin themselves.

Unlike isinglass the shreds of gelatin, as already noticed, examined with the microscope, are seen to be composed of a transparent and perfectly homogeneous substance (see fig. 137).

Glue is quite a distinct manufacture from gelatin, and is seldom carried on by the same parties. It is made from bones, refuse pieces of skins, and hoofs.

Dry gelatin, when quite pure, is colourless, transparent, elastic and yet brittle, tasteless and odourless, heavier than water, and insoluble in alcohol or ether. When immersed in cold water it swells up and absorbs about 40 per cent. of that liquid. It is soluble in hot water and is precipitated from its concentrated aqueous solution by alcohol. By prolonged boiling it loses its power of gelatinising, and the solution on evaporation leaves a residue which attracts moisture from the air. It contains a small quantity of sulphur, and yields, as the average of all the reliable analyses made, 17·9 per cent. of nitrogen.

It is precipitated by tannic acid, but not by salts of lead, alum, or by sulphate of iron.

Its aqueous solution is very prone to putrefaction; it becomes acid, and afterwards gives off ammonia freely. This property of first becoming acid is said to be peculiar to gelatin.

Gelatin is dissolved by concentrated sulphuric acid in the cold. The solution, when diluted with water and boiled, yields *leucin* and *glycocin* or *sugar of gelatin*. By boiling a solution of gelatin with dilute sulphuric acid for several days, Gerhard obtained sulphate of ammonia and a considerable quantity of saccharine matter convertible into alcohol and carbonic acid by fermentation.

It is oxidised by boiling nitric acid, *oxalic* acid and other compounds being formed.

Gelatin dissolves phosphate of lime, forming with it, in some instances, chemical combinations.

The precipitate of gelatin with gallo-tannic acid is insoluble in water, alcohol, and ether; and when dried contains about 74·6 per cent. of gelatin, but the composition of the precipitate does not appear to be very constant.

Gelatin, according to Liebig, possesses the property of inducing saccharification.

THE ADULTERATIONS OF GELATIN.

The addition of a small quantity of salt, with the view of ensuring the preservation of the gelatin, is, of course, allowable; but *salt* is frequently added in large quantities; it then causes the gelatin to absorb moisture from the atmosphere, whereby its weight is much increased.

In some cases, gelatin is adulterated with *sugar*, either brown or white, not to any considerable extent, except with some of the inferior qualities, such as are so largely used by the manufacturers of canister meats.

The jellies in bottles, and those sold by confectioners as isinglass and calves' feet jelly, consist principally of gelatin variously flavoured. Jellies made from calves' feet are much less firm, and dissolve quicker than those made from gelatin, if kept in a warm room.

THE DETECTION OF THE ADULTERATIONS OF GELATIN.

The adulteration of gelatin with *salt* may be thus detected:—10 grammes of the gelatin must be incinerated and the ash tested for salt—the quantity of which present may be determined, if necessary, by the process given under 'Butter.'

For the detection of the *sugar* the following process may be followed:—Dissolve the gelatin in water; precipitate with tannic acid; filter, remove excess of tannic acid by the addition of a solution of acetate of lead, filter again, and free the filtrate from lead by means of sulphuretted hydrogen. Convert the cane sugar into glucose by boiling with dilute sulphuric acid, and estimate the sugar with the copper solution.

Another method is the following:—Soften the gelatin by maceration in cold water, boil in alcohol; this will take up the sugar and leave the gelatin.

CHAPTER XXIV.

UNWHOLESOME AND DISEASED MEAT.

Closely connected with the subject of the adulteration of food is the condition as to soundness and wholesomeness of the various articles consumed as food, and with this subject it is necessary that the analyst should be acquainted, as he will often be called on for his opinion and advice. We have already referred to the case of damaged flour, but in the present article we propose to treat somewhat at length of *unwholesome and diseased meat.*

It will assist the understanding of what follows if we give the analysis and composition of fresh meat, as also of its ash.

Composition of Fresh Meat.

(Moleschott; mean of many analyses.)

Water	73·4
Soluble albumen and hæmatin	2·25
Insoluble albuminous substances, as fibrin	15·2
Gelatinous substances	3·3
Fat	2·87
Extractive matters	1·38
Kreatin	0·068
Ash	1·6

Composition of the Ash of Meat.

(Parkes' 'Hygiene,' p. 167.)

	Fresh Beef.	Salt Beef.	Fresh Pork.	Ham or Salt Pork.
Total ash, per cent of undried substances	1·6	1·5	1·11	6·6
Chloride of sodium	0·310	0·691	0·012	5·7
Chloride of potassium	0·154	—	—	0·173
Potash	0·540	0·398	0·420	0·350
Soda	0·026	—	0·045	—
Lime	0·051	0·012	0·083	0·027
Magnesia	0·023	0·030	0·004	0·035
Oxide of iron or phosphate	0·011	0·017	0·494	0·006
Phosphoric acid	0·435	0·346	0·054	0·312
Sulphuric acid	0·036	0·010	—	0·013
Chlorine	—	—	—	—
Silica	0·014	0·004	—	—

It will be observed that the above analyses take no notice of the carbonic acid which occurs in the ash of meat, and which is said to amount to 8 or 9 per cent. This is supposed to be derived from the destruction of the *lactic acid* during incineration.

It is stated that an ox should weigh not less than 600 lbs., but it is sometimes as much as double this. A cow may weigh considerably less than the above. An ox yields about 60 per cent. of meat, exclusive of head, feet, lungs, and intestines, but a pig as much as 80 per cent. of available food. A sheep weighs from 60 to 90 lbs. Taking the whole animal, 20 per cent. should be allowed for the bones.

It is not easy to determine the age of an animal when living, and it is still more difficult to do so when dead. The indications of the age are mainly furnished by the teeth and horns, but the details are too technical to be described in this place. They will be found, however, in Parkes' 'Hygiene.'

GENERAL CHARACTERS AND EXAMINATION OF MEAT.

The muscles of sound flesh should be firm, elastic, pale for the young animal and darker coloured for the old one, and when cut across a little reddish juice should flow out after some time. The flesh should not be of a deep purple tint, as this is a sign that the animal has not been slaughtered, but has died without being bled. There should be no unpleasantness of odour and no smell of physic, for diseased meat has a sickly corpse-like smell.

There should be no marbling of the flesh or softening or purulent fluid in the intermuscular cellular tissue. 'Bad meat is wet, flabby, and sodden, with the fat looking like jelly or wet parchment.' —*Letheby.*

The fat should be firm and without being marked with hæmorrhagic spots. Meat as it becomes putrescent begins to emit an unpleasant odour, the fibres become paler or even turn greenish. Parkes says it is a good plan to push a clean knife into the flesh up to the hilt. In good meat the resistance is uniform, while in putrefying meat some parts are softer than others. The smell of the knife is also a good test. *Cysticerci* and *trichinæ* should be searched for.

In temperate climates, twenty-four hours after killing, the marrow of the hind legs is of a light rosy red colour and moderately firm. If it is soft, brownish, or exhibits black points, the animal has been sick or putrefaction has commenced.

The lungs and liver should both be examined with a view to discover in the one case *Strongylus filaria*, and in the other *Distoma hepaticum*; also for the detection of organic changes, such as the presence of small abscesses.

Another means of judging of the quality of meat is to observe the effects of cooking, to ascertain how much it loses in roasting and boiling, and whether the meat becomes hard or not.

Again, the microscope is capable of affording valuable information as to the quality and condition of meat; whether the muscles are sound, over-fat, or changed by decomposition or disease. In the cattle plague they are said to be in a degenerative condition. Further it is by means of the microscope that the presence of the various parasites which infect the flesh of animals is discovered.

Care must be taken not to confound the capsules of trichinæ with *Rainey's capsules*, called *psorospermia*. These are almost transparent bodies, oval, spindle-shaped, sometimes pointed at one end and rounded at the other, or they are kidney-shaped.

The investing membrane of these capsules exhibits delicate markings, caused by a linear arrangement of minute hair-like fibres. 'They sometimes are pointed, and their appearance under a high power, 1,000 diameters, is as if the investment consisted of very delicate, transparent, conical hairs, terminating in pointed processes. The contents of these cysts consist of granular matter, the granules or particles of which when mature are oval, and which adhere together so as to form indistinct divisions of the entire mass. The length varies from $\frac{1}{300}$ to $\frac{1}{4}$ of an inch. They are usually narrow; they lie within the sarcolemma and appear often not to irritate the muscle.'—*Parkes.*

No injurious effects have been produced on men by these bodies, notwithstanding the frequency of their occurrence in the flesh of domestic animals, nor indeed have they ever been found in the muscles of men; but in the pig they have been productive of illness, particularly paralysis of the hind legs and a nodular eruption. In sheep they sometimes affect the muscles of the gullet, producing swellings, often as large as a nut, and containing a milky purulent-looking fluid, which contains myriads of these capsules. Sheep thus affected often die suddenly.

Bodies also termed *psorospermia*—of an oval or rounded form—according to Parkes, 'at first with granular contents and then with aggregations of granules into three or four rounded bodies, on which something like a nucleolus is seen,' have been met with in the liver and other parts of the rabbit, in the dog, and in the liver of man. They are quite distinct from Rainey's corpuscles.

POISONOUS BUT NOT DISEASED MEAT.

It is well known that the flesh of animals not diseased may produce injurious and even poisonous symptoms. This must arise in some cases from the presence in the animals themselves of some poisonous substance.

These effects follow especially the consumption of certain descriptions of fish. Pappenheim gives a list of no less than forty fishes which sometimes exert poisonous effects. Among these are *Clupea harengo minor*, or *little herring: Zeus gallus* or *silver fish*, the *pilchard*, the *yellow-billed sprat: Aplodactylus punctatus* or *bladder fish*, and

Coracinus fuscus major, or *grey snapper*. So venomous are some of these fish that, when eaten by other fish, the flesh of these in their turn also becomes poisonous. It is related that the yellow-billed sprat is so poisonous, that persons who have partaken of it have been known to expire with the fish in their mouths. The effects produced by eating the bladder fish are almost as great.

Maletta venenosa is only poisonous at a particular time, and it is believed that it owes its poisonous properties to a green monad upon which it then feeds.

Oysters and *mussels*, even when undecomposed and in good condition, have also been known to produce similar symptoms.

Among mammalia the flesh of the *pig*, not apparently diseased, has given rise to diarrhœa and other choleraic symptoms.

Ill and indeed poisonous effects have been known to result sometimes from *brine* which has been used several times. These probably depend upon the production of some animal poison, the nature of which has not hitherto been determined.

But meat is sometimes rendered poisonous by the food upon which the animals have fed previous to their being killed.

Thus the flesh of hares which have fed upon the *Rhododendron chrysanthemum* is poisonous; that of birds is sometimes rendered so by feeding upon the buds of *Calmia latifolia*; while it is related that a whole family at Toulouse were poisoned by partaking of snails which had eaten the leaves of *Coriaria myrtifolia*. Again, milk is often rendered poisonous by the herbage upon which the cows have fed.

PUTRID MEAT.

There does not appear to be any reason to believe that as a rule meat, including flesh and fish of all kinds, more or less decomposed, is productive of injurious consequences. Nearly all game is somewhat decomposed when partaken of, and yet hurtful effects rarely ensue. There is no doubt that the cooking contributes greatly to this immunity.

Still in some cases the consumption of meat altered by decomposition does give rise to vomiting, diarrhœa, and to symptoms resembling typhus.

The consumption of partially decomposed sausages and pork pies has been followed by symptoms of poisoning accompanied by severe intestinal disorder, and with nervous depression and collapse, ending frequently in death. M. Vanden Corput attributes the effects in the case of sausages to a fungus which he terms *Sarcina botulina*.

Effects somewhat similar have been known to result from the consumption of *cheese*, and even *bacon*, *ham*, *salt beef*, and *salt fish*, these articles having been usually in a decaying and mouldy condition; and it is probable that the poisonous effects are due also in these cases to the presence of a fungus.

Decomposing mollusca also sometimes produce marked symptoms of poisoning, but ordinary fish in a state of decomposition do not usually give rise to any bad effects.

DISEASED MEAT.

The flesh of animals killed on account of recent *accidents* may, as might be supposed, be eaten with impunity.

The flesh of *overdriven* and *tortured* animals, according to Professor Gamgee, often contains a poison which produces an eczematous eruption of the skin of those who handle it, and the eating of such flesh is said to have been attended with injurious effects.

The meat of animals which have suffered from some simple *inflammatory disease*, as *pneumonia*, and which have been killed, is commonly eaten, and also without injurious effects, provided the inflammation has not progressed to the stage of the formation of matter or pus.

THE DISEASES OF CATTLE.

Many of the particulars embraced under the above heading are taken from Parkes' 'Practical Hygiene.'

The principal diseases to which cattle are subject are *epidemic pleuro-pneumonia*, which has the symptoms of ordinary pleuro-pneumonia, but is distinguished by its being epidemic.

Foot and mouth disease, also termed *murrain* or *Eczema epizootica*.

Cattle plague or *rinderpest*, *Typhus contagiosus*, has for its symptoms great and early prostration, shivering, running from the eyes, nose, and mouth, abdominal pain and diarrhœa.

Anthrax or *malignant pustule*, if combined with erysipelas, *Erysipelas carbunculosum*, is called *black quarter*, *quarter ill*, or *black leg*.

Of course cattle are subject likewise to a variety of other diseases, including *dropsical affections* from diseases of the liver, kidney, or heart.

Sheep are subject to the same diseases as oxen and cows, but they are liable to certain disorders peculiar to themselves. One of these is *braxy* or *splenic apoplexy*. This is considered by Professor Gamgee to be a kind of anthrax.

It is said to kill fifty per cent. of all the young sheep that die in Scotland. The animals have a staggering gait, bloodshot eyes and rapid breathing.

Sheep are also liable to *smallpox*, *Variola ovina*.

They are also subject to a so-called *phthisis*, which is produced by the presence in the lungs of the ova of the *Strongylus filaria*.

The *pig*, in addition to other diseases already noticed, suffers from a disorder which has been called *hog cholera*, and which is supposed to be a rapid form of typhoid.

The flesh of animals which have suffered from *chronic wasting* diseases is usually pale, and is very prone to undergo putrefaction. It frequently gives rise to sickness and diarrhœa, the effect of partaking of the diseased meat manifesting itself, as might have been expected, first on the gastro-intestinal canal.

The evidence hitherto obtained goes to show that the flesh of animals which die of *epidemic pleuro-pneumonia* may be eaten without injury, but Dr. Livingstone states that the use of this flesh produces carbuncle, and the virus, he affirms, is not destroyed by boiling or roasting. 'Now it is a remarkable circumstance,' writes Dr. Letheby, 'that ever since the importation of this disease into England from Holland in 1842, the annual number of deaths from carbuncle, phlegmon, and boils has been gradually increasing.'

There is no doubt but that the consumption of the flesh of animals which have been affected with *malignant pustule* is attended with danger. The increase in the number of cases of malignant pustule in man has been ascribed to this cause. It has also been supposed that boils are produced by the use of meat of this kind. It is certain that the disease may be communicated to the human subject by inoculation.

On the other hand, several instances have been recorded in which no ill effects have been produced by partaking of the boiled or roasted flesh of animals so diseased, and this in cases in which it was readily propagated by inoculation.

The flesh of animals affected with *black quarter*, or *Erysipelas carbunculosus,* which possibly is but a modification of malignant pustule, has also been known to give rise to fatal disease.

With regard to the effects of the consumption of the flesh of sheep who have died of *splenic apoplexy* or *braxy,* the evidence is again very contradictory, but there is no doubt that it does give rise to blood-poisoning and to death in some cases. It would appear that pigs, dogs, and fowls are less affected by it than sheep, goats, or horses. Dr. Smith states that the shepherds in the Highlands of Scotland eat by preference braxy sheep and are quite healthy, but then the flesh is never cooked until it has been steeped for two months in brine, and has been suspended for some time from the kitchen roof. It is preferred to ordinary salt mutton, because of its possessing somewhat the flavour of game.

Dr. Letheby writes, in reference to this question—'Every now and then, however, when perhaps the diseased parts have not been entirely removed, or when the salting has not been sufficiently prolonged, or the cooking has not been thoroughly effected, the most serious consequences result from it, insomuch that many medical practitioners who are acquainted with the habits of the Scotch shepherds in this respect, and have seen the mischief occasioned by the meat, declare that braxy mutton is a highly dangerous food for man.'

The flesh of animals affected with the *smallpox* produces sickness and diarrhœa, with sometimes febrile symptoms.

No ill effects have been traced to the use of meat which has been affected by the *foot and mouth disease.*

The evidence with respect to the effects of the use of the flesh of animals which have died of the *cattle plague* is somewhat contradictory, but it is certain that it is often consumed with impunity. Renault asserts that no danger is to be apprehended from the cooked flesh of cattle, pigs, or sheep which have died of any contagious disease.

No ill effects have been traced to the use of the flesh of pigs which have been affected with *scarlet fever* or *pig typhus.*

The flesh of horses affected with *glanders* and *farcy* does not appear to exert any injurious effects.

PARASITIC DISEASES.

Measles in the pig is caused by the presence in the muscles of *Cysticercus cellulosus.* The vesicles or sacs containing the cysticerci are of about the size of a hemp seed, and hence are visible to the naked eye, their nature, when examined with a low power of the microscope, being readily ascertained. They may sometimes be distinguished in the mucous membrane under the tongue, or on the conjunctiva, or sometimes they may be discovered by examining a small piece of muscular tissue removed from the tongue or any other convenient part. In some cases they are so abundant as to cause the flesh when cut to emit a crackling sound. In many countries they are of extremely common occurrence, as in North-West India. Salting does not kill them, and they may be readily detected in salted meat. A temperature of 100°C. is said to kill the cysticerci, as also smoking the flesh containing them.

'The sac contains a little creature with a sort of tuberculated head, crowned with a coronet of hooks, and having a bladder-like tail attached to it. Soon after it is swallowed the enclosing sac is dissolved by the gastric juice, and the creature being liberated, passes into the intestines and there fixes itself by its little hooks, and quickly grows, joint after joint, into a tape-worm.'—*Letheby.*

The cysticercus occurs in the flesh of other animals besides the pig, as the ox. The cysticercus of the pig gives rise to the variety of tapeworm called *Tænia solium,* and that of ox and cow to *Tænia mediocanellata.* The ova of these, when introduced into the stomachs of animals or of the human subject, become hatched, passing like the trichinæ through its walls, and so being distributed through the body, becoming ultimately encysted.

Hydatid disease.—Again, the tapeworm of the dog, *Tænia echinococcus,* becomes the *hydatid* in man and some other animals. This in sheep often infests the brain, producing what has been called *staggers.* In man the chief seat of hydatids is the liver.

The *gid, sturdy,* or *turnsick,* is caused by the development of *cœnurus cerebralis* in the brain.

The Trichina disease.—Like the *Cysticercus cellulosus,* the *Trichina spiralis* is particularly liable to infest the flesh of the pig.

The best method of examination is the following:—A thin section of the flesh should be immersed in a solution of liquor potassæ, containing 1 part of the alkali to 8 of water, and allowed to remain for a few minutes only until the muscle becomes clear; if allowed to remain too long the trichinæ will be destroyed. The white specks then become clearly visible, and the worm will usually be seen coiled up, and, if not visible, it may often be rendered so by the addition of a drop or two of weak hydrochloric acid. The parts said to be most infested are the diaphragm, the intercostal muscles, and those of the eye and jaw.

The presence of trichinæ during life may sometimes be determined by an examination of the muscles under the tongue.

Pork infected with trichinæ 'is generally darker than usual on account of the irritating or inflammatory action of the creature lodged in the muscles, and when the parasite is encysted the meat presents a speckled appearance, the minute white cysts containing the worms being just visible to the naked eye.' As found in the human subject it is usually in the encysted state, 'when it has passed beyond its dangerous condition and has become harmless. In most cases, when thus discovered, there is no record of its action, and therefore it was once thought to be an innocent visitor, but we now know that while it was free, that is, before nature had barricaded it up in the little cyst, its presence was the cause of frightful disorder, killing about 50 per cent. of its victims in terrible agony.'—*Letheby.*

The young worms, being hatched in the body, migrate to all the muscles, 'causing the most excruciating pain, so that the patient, fearing to move his inflamed muscles, would lie motionless on his back; and, if he did not die in this state of the disorder, nature came to the rescue and imprisoned the creature by surrounding it with a fibrinous cyst, where it lives for years, being ready at any moment to acquire activity when it is swallowed and released from its cell.'—*Letheby.*

The ordinary mode of their propagation is by eating the raw or imperfectly cooked flesh. Cooking and smoking the flesh are but imperfectly protective. A temperature from 66° to 68° C. destroys the trichinæ, but cold and decomposition of the meat do not impair their vitality.

The rot.—Another disease occasioned by a parasitic animal, the *fluke, Distoma hepaticum,* is the rot. This infests particularly the livers of animal and men, sheep being very liable to it, especially in wet seasons.

'The way in which the disease is produced in sheep is curious. Ova are passed from the gall-bladder of infected animals into the intestines, and so upon the land; finding a moist situation they are soon hatched into ciliated embryos, which swim about and become developed into cylindrical sacs of minute hydatids; these attach themselves to some mollusc, as a small snail. In wet weather the infected snails crawl upon the grass and are eaten by the sheep, and then the hydatid speedily changes his condition and becomes a fluke. When it is found in the body of man it has, perhaps, been drunk with water or eaten with some aquatic plant, as watercress, &c.'—*Letheby.*

There is no evidence to show that the liver of the sheep containing *flukes* or *echinococci*, when consumed in this country, gives rise to the same disease, but in Iceland the disease is derived from sheep and cattle, which in their turn become infected through the tænia of the dog. The symptoms of fluke disease are dulness, a rapid wasting, diarrhœa, yellowness of the eyes, falling of the hair, and dropsical swellings.

Strongylus filaria.—This parasite occurs in the lungs, giving rise to a disease of those organs resembling phthisis.

In times of scarcity of meat, as in war, it may be necessary to allow of the use of the meat of diseased animals, but in this case certain precautions should be observed. The animals should be bled freely, the flesh or muscles only should be used, and the meat should be thoroughly cooked. The flesh of animals affected with *smallpox*, *cysticerci* and *trichinæ* should not on any account be used.

CHAPTER XXV.

POTTED MEATS AND FISH AND THEIR ADULTERATIONS.

DEFINITION OF ADULTERATION.

Meat or fish not acknowledged in the names under which the articles are sold, and any foreign vegetable or mineral substance.

Potted meats and fish are adulterated, first, by admixture with substances added for the sake of bulk, weight, and cheapness; and second, with others designed to heighten their colour.

Thus they are sometimes adulterated with large quantities of *flour*, and in other cases, it is alleged, with even *chalk* and *plaster of Paris.*

Again, *sprats* and *other cheap fish* are often ground up, and after being seasoned, are sold either in the separate or mixed state for real Gorgona paste.

Lastly, the majority of these pastes were formerly very commonly coloured with large quantities of *Venetian red* and *bole Armenian.*

RESULTS OF THE EXAMINATION OF SAMPLES.

Twenty-eight samples of potted meats and fish were examined a few years since, and with the following results:—

1. The samples of *potted tongue* and *ham* were entirely free from adulteration.
2. Four out of the five samples of *potted beef* were artificially coloured by means of the red earth, *bole Armenian.*
3. The whole of the samples of *potted bloaters* examined were highly coloured with the before-named earthy substance.
4. One of the samples of *bloater paste* was adulterated in addition with a large proportion of *starch* or *flour*, probably wheat flour boiled.
5. The entire of the samples of *anchovy paste* analysed were still more highly, and even vividly, coloured with very large quantities of *bole Armenian.*
6. Two of the *anchovy pastes* were in addition adulterated with *flour*; one with a large percentage of *wheat flour.*
7. Of the twenty-eight samples of *potted meats* and *fish* subjected to analysis, no less than twenty-three were more or less impregnated with the red earthy material, *bole Armenian.*

This picture of the adulteration of potted meats and fish is surely bad and disgraceful enough, but we are happy to say that since the time when the analyses above recorded were made a very great improvement has taken place in the preparation of these articles, and *bole Armenian* is now but seldom made use of.

The difference in the appearance presented by the uncoloured samples contrasted with those in which the bole Armenian had been added was most striking, and usually sufficient to enable the observer to distinguish by the eye alone the samples to which this scandalous addition had been made. While in the one case the paste was of a pale pink and perfectly natural hue, in the other the colour was such as the flesh, when pounded, of no fish or animal ever presents, it being a deep brick red.

In the report on bottled anchovies we have shown that one of the principal reasons why artificial colouring matters are employed is to conceal the dirt contained in the brine in which the fish is imported. In the present instance there is not even this poor excuse; the only purpose served by the employment of the bole Armenian being to cause the potted articles to present a striking appearance, but one which at the same time is, in our opinion, most unnatural, and but little inviting.

In the case too of potted meats and fish, the colouring ingredients cannot, as in anchovies, be got rid of in a measure by washing; for since they are incorporated with the paste, they must be entirely consumed with the meat or fish.

That the practice of adding large quantities of coloured earthy substances to articles of diet is dirty, injurious to health, and in some cases even dangerous to life, cannot be doubted. The chief medicinal ingredient in bole Armenian is oxide of iron; this, although not dangerous, might in some instances be productive of prejudicial effects; but it sometimes happens that other red earths are used, and these, as well as also occasionally, although rarely, bole Armenian itself, are contaminated with red lead. *For this poisonous substance each of the above twenty-eight samples were separately analysed, without however, we are happy to state, a particle of it being discovered in a single instance.*

Mr. Richardson, then officer of the Local Board of Health of Newton Heath, near Manchester, gave the following evidence before the Committee on Adulteration, of 1855, in regard to the addition of *horseflesh* to potted meats, sausages, &c.:—

'We have in Newton five knackers' yards, and there is only one in Manchester. The reason is, that they have so much toleration in Newton; and it has been a source of great profit to them, because they have the means of selling the best portions of the horseflesh to mix with the potted meats.

'I can say for a fact that the tongues of horses particularly, and the best portions, such as the hind-quarters, of horses, are generally sold to mix with collared brawn, or pigs' heads as they are called with us, and for sausages and polonies. I understand, also, from those who have been in the habit of making them, that horseflesh materially assists the making of sausages; it is a hard fibrine, and it mixes better and keeps them hard, and they last longer in the shop-window before they are sold, because otherwise the sausages run to water and become soft and pulpy. I believe horseflesh also materially assists German sausages; it keeps them hard.'

To the above account we may add that German sausages and polonies were at one time frequently coloured with large quantities of *Venetian red* or *reddle.*

DETECTION OF THE ADULTERATIONS OF POTTED MEATS AND FISH.

As we have seen, the chief adulterants of these articles are flour or starch, red ferruginous earths, as Venetian red and reddle, and sometimes, it is alleged, carbonate or sulphate of lime. Methods have been given elsewhere in this work for the detection and estimation of each of these substances, so that it is unnecessary to repeat them in this place.

CHAPTER XXVI.

ANCHOVIES, THEIR SUBSTITUTIONS AND ADULTERATIONS.

DEFINITION OF ADULTERATION.

Admixture with or substitution of any other fish than the anchovy; bole armenian or any other coloured earth.

We find but little, in works on the adulteration of food, in reference to the substitution of inferior kinds of fish for this much esteemed variety; although, if common report is to be credited, but few articles of consumption are more subject to substitution and adulteration than the anchovy, whether in the entire state or in the forms of paste and sauce.

On the present occasion we have to treat of the entire fish only.

Before proceeding to give the results of the examination and analyses of various samples of anchovies, as vended in the metropolis, we insert an original figure, as also a scientific description of the fish, taken from Yarrell's excellent work on the British Fishes:—

'*Generic characters.*—Distinguished from the herring in having the head pointed; the upper jaw the longest; the mouth deeply divided; the opening extending backwards behind the line of the eyes; the gape branchial apertures very large; the ventral fins in advance of the line of the commencement of the dorsal; abdomen smooth; branchiostegous rays twelve.

'I have followed Dr. Fleming, in preserving to the anchovy the old name by which it was formerly known. It was called *Lycostomus*, from the form of its mouth; and *Engraulis encrasicolus*, because, from its bitterness, it was supposed to carry its gall in its head. For this reason, the head, as well as the entrails, are removed when the fish is pickled.

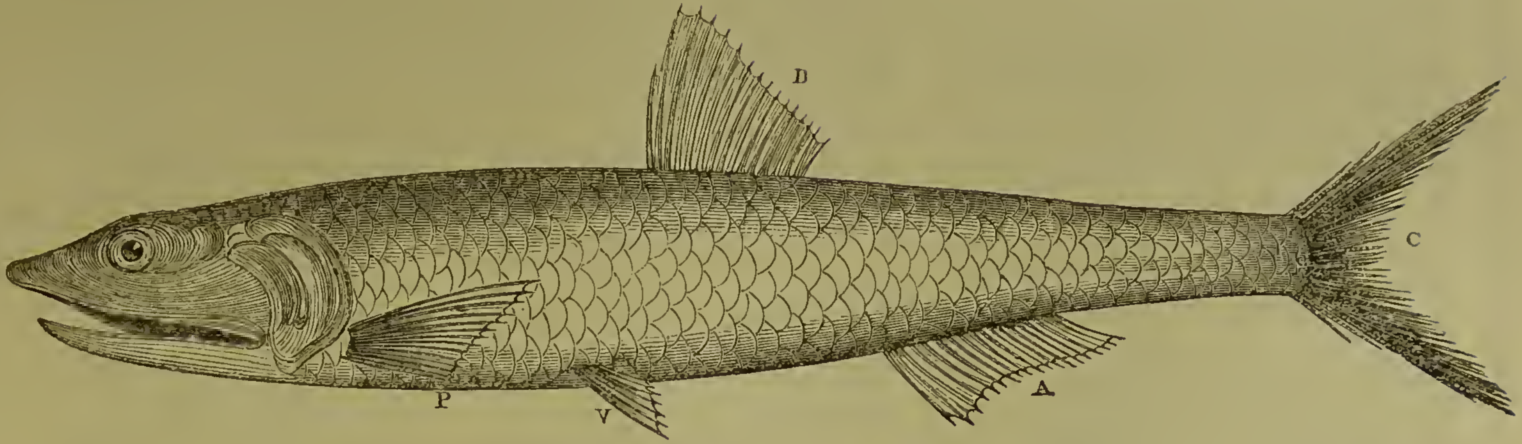
'The anchovy is a common fish in the Mediterranean from Greece to Gibraltar, and was well known to the Greeks and Romans, by whom the liquor prepared from it, called *garum*, was in great estimation. Its eastern range is extended into the Black Sea.

'The fishing for them is carried on during the night, and lights are used with the nets.

'The anchovy is common on the coasts of Portugal, Spain, and France; it occurs, I have no doubt, at the Channel Islands, and has been taken on the Hampshire coast and in the Bristol Channel. In the Appendix to Willughby's work, it is mentioned as having been

Fig. 138.

THE TRUE ANCHOVY. *Engraulis encrasicolus*, FLEMING.



D, dorsal fin ; P, pectoral fin ; V, ventral fin ; A, anal fin ; C, caudal fin.

taken on the coast of Wales; Pennant obtained it near his own residence, at Downing in Flintshire; and Mr. Bicheno has very recently obtained several on the coast of Glamorganshire. It is said to be sold frequently in Liverpool market, and is reported to be at this time an inhabitant of the piece of water below Blackwall, called Dagenham Reach.

'Its range to the north is extensive, as it is occasionally taken in the Baltic, and on the coast of Noway; but is not included by Linnæus in his *Fauna Suecica.*

'The anchovy appears to attain a much larger size than has usually been accorded to it: from four to five inches in length is the more ordinary size; but Mr. Couch says—'I have seen it in the Cornish seas of the length of seven inches and a half; and I have met with specimens from autumn, through the winter, to the middle of March. It is therefore probable that a fishery might be established with good prospect of success, for though the nets employed for other fish can take but few of them, the numbers found in the stomachs of the whiting, and other ravenous fishes, show that they are in considerable abundance.

'The anchovy is immediately recognised among the species of the family to which it belongs by its sharp-pointed head, with the upper jaw considerably the longest. The length of the head, compared with the length of the body alone, is as one to three; the depth of the body but two-thirds of the length of the head, and compared to the length of the whole fish, is as one to seven; the first ray of the dorsal fin arises half way between the point of the nose and the end of the fleshy portion of the tail; the third ray of the dorsal fin, which is the longest, is of the same length as the base of the fin; the pectoral fin small; the ventral fins arise in a vertical line in advance of the commencement of the dorsal fin, which is over the space between the ventral and anal fins; the base of the anal fin is as long as the distance from its commencement to the origin of the ventral fins; the rays short; the tail deeply forked. The fin rays in number are:—

D, 14; P, 15; V, 7; A, 18; C, 19.

The breadth of the eye is one-fifth of the length of the whole head; the peculiarity in the comparative length of the jaws has been previously noticed; the gill covers are elongated; the scales of the body large and deciduous; the colour of the top of the head and back blue, with a tinge of green; irides, gill covers, sides and belly, silvery white; the fins delicate in structure, and greenish white; the membranes connecting the rays almost transparent.

'In a series of notes on the occurrence of rare fish at Yarmouth and its vicinity, with which I have been favoured by Dawson Turner, Esq., there is mention of a specimen of the anchovy, taken on the beach, which measured six inches and a half in length; an additional proof of the large size acquired by this fish on our shores.'

To the above we would add a description of the condition of the true anchovy when bottled.

The head and intestines are removed; the scales and fins, with the exception of the pectorals, are allowed to remain; the fish is of small size, silvery, and rather flat, the line of the back slightly curved, and the flesh is usually of a pink or salmon colour, the depth varying considerably in different samples according to age: if an anchovy be three months old, it will be pale; if six months, rather pink; and if twelve months, a beautiful deep pink colour.

The number of the fin-rays, which may be counted in the fish in its preserved state, is greater than that given in the description we have quoted; thus, when complete, the dorsal fin is composed of sixteen rays, the anal fin of nineteen, and the caudal of twenty-six rays.

Anchovies are imported in barrels, and are preserved in brine made with rock salt; the bottling is performed in this country, chiefly by wholesale pickle and fish-sauce makers.

THE ADULTERATIONS OF ANCHOVIES.

Several kinds of fish are either substituted for, or mixed with, the genuine Gorgona anchovy.

The chief of these are *Dutch*, *French*, and *Sicilian fish*, and occasionally *Sardines* and *Sprats*.

In addition, the brine in which the fish are preserved is almost invariably highly coloured with large quantities of *bole Armenian* and *Venetian red*.

Bole Armenian is a red ferruginous earth, often prepared artificially by mixing together Venetian red and chalk. The reason of its being added to anchovies, it is alleged, is to improve the appearance of the fish; but the real reason is to conceal the dirt contained in the brine which surrounds the fish.

In eating anchovies some persons first wash the fish, by which means they no doubt get rid of much of the red earth and dirt; but others eat the fish just as it comes out of the brine.

From an examination, made some years since, of *twenty-eight* samples of anchovies, mostly in bottles, it appears,

That *seven* of the samples consisted entirely of DUTCH FISH.

That *two* consisted of a mixture of DUTCH FISH and Anchovies.

That the brine in *twenty-three* of the samples was charged with either *bole Armenian* or *Venetian red*, the quantity varying considerably in amount; but in most cases the brine was saturated with these earthy powders to such an extent that they might be obtained and collected from the bottom of the bottles almost by teaspoonfuls.

It is not to be inferred that those samples in which no Dutch fish were detected consisted of the true anchovy, since we have ascertained that two other kinds of fish besides the Dutch are commonly imported and sold as 'true anchovies,' and 'real Gorgonas,' namely, French and Sicilian fish.

Now, we have no doubt but that the majority of the above samples consisted entirely of one or other of these fish; we hesitate, however, to pronounce a positive opinion in each case. Although it is not difficult to distinguish French and Sicilian fish from the Gorgona anchovy when first taken from the barrels in which they are imported, yet when contained in bottles the discrimination is often a matter of considerable difficulty, and in many cases is even scarcely possible. This arises from the squeezing and mutilation of the fish in the process of bottling, as well as from the altered appearance due to the red earthy matters with which they are commonly covered. Whether those engaged in the trade are acquainted with any practical characters by which the discrimination of the fish, even when thus altered, may be effected we know not.

We have, however, much reason to think that Sicilian and French fish, notwithstanding their resemblance to the true anchovy, may be distinguished by experienced persons, even when bottled. With a view to determine this point, we forwarded to a person engaged in the anchovy trade twelve of the samples referred to, each being labelled with a distinct number; the following is his report:—

1. Gorgona.
2. French fish.
3. Ditto.
4. Gorgona, not fine.
5. Sicilian fish.
6. Gorgona.
7. Dutch, inferior.
8. Sicilian, good quality.
9. Gorgona.
10. Dutch fish.
11. Sicilian.
12. Sicilian, best quality.

If this list be correct, then NOT ONE-THIRD OF THE TWENTY-EIGHT SAMPLES EXAMINED CONSISTED OF GORGONA ANCHOVIES.

The practice of imparting an unnaturally red colour to the fish and brine, by means of Venetian red and bole Armenian, is in the highest degree reprehensible. To saturate an article of food with large quantities of earthy colouring matter is objectionable on the score of cleanliness; it is equally so as regards health, for this earth contains a large quantity of iron. Now, this medicine is not suited to all cases, and it may even, in some instances, be productive of mischief; at all events, when it is desirable to take iron, we should prefer that it be prescribed under the advice of a physician, and not administered in an article of food by our grocer, fishmonger, or Italian warehouseman.

Again, it occasionally happens that Venetian red contains red lead; and although in the analyses we have made we are happy to state that *we have not detected that poisonous metallic oxide in a single sample*, there is no question but that red lead is occasionally to be found in bottled anchovies.

Anchovies, even when thus coarsely reddened, and put in glass bottles, are not particularly sightly objects. Both for convenience and appearance it would be much better that they should be enclosed in open-mouthed earthen jars, which might be made of different patterns, and as ornamental as desired; by this means the necessity for colouring would be done away with, and there would be no occasion to use wax and resin, themselves frequently coloured with red lead, to coat the corks, and some of which substances, on the bottles being opened, usually find their way into the contents. Now that glass is so cheap, if bottles continue to be used they should, at all events, be furnished with glass stoppers in place of corks.

THE DETECTION OF THE ADULTERATIONS OF ANCHOVIES.

The *Dutch* fish may be distinguished from the true anchovy by its being invariably deprived of its scales, by its large size, white flesh, general coarseness, and by the very evident scale-marks which extend over the whole surface. The fins have the same disposition as the true anchovy, and the same number of rays.

The French, and especially the Dutch, fish are not only of much less value, but also greatly inferior as articles of diet to the true anchovy. The difference in their cost may be estimated by the fact that dealers find it worth their while to mix them in different proportions in even the same bottle. There is no difficulty in distinguishing the Dutch fish by the characters pointed out above; but it would be very difficult to discriminate between the larger samples of the French anchovies, when denuded of their scales, and that which in this article is denominated *Dutch fish*, and hence we infer that the two may possibly be separate states and conditions of one and the same species.

The *French fish* is caught off the coasts of Nantes and Nice, and is imported into this country in barrels packed in brine made with rock salt.

It closely resembles in its characters the true anchovy, and is probably of the same genus. Like the anchovy, it is deprived of its head and intestines, but the scales, and not unfrequently the branchial rays and pectoral fins, are entire. Moreover, the fish is usually somewhat larger, thicker across the back, tapers more towards the tail, and the flesh is much whiter than the Gorgona anchovy. These differences, however, are not sufficiently marked in general to allow of this fish, *when bottled*, being satisfactorily distinguished from the true anchovy by an ordinary observer. Its commercial value is about one-half that of the Gorgona anchovy.

The *Sicilian fish* resembles the Gorgona anchovy very closely, of which, by some, it is considered to be the young, it being smaller. Whether it be a state of that species or of the same genus we are not able to determine with certainty; its value is at least one-third less than that of the Gorgona anchovy.

In none of the samples have we met with either *sprats* or *sardines*, although there is no doubt that both these fish have been, and are still occasionally, sold as real Gorgona anchovies. The sprat may be readily distinguished from the anchovy by the dorsal fin, which consists of seventeen rays, but more particularly by the position of the ventral fin, which is placed in a vertical line directly under the first dorsal fin-ray.

The sardine is a shorter and thicker fish than the anchovy; it has white flesh, and the relative position of the ventral and dorsal fins is different.

The detection of Venetian red and bole Armenian.—The presence of these earths is sufficiently indicated by the red colour of the brine and by the colour and earthy character of the precipitate. In order to obtain them in a separate state, the fish should be repeatedly washed, the washings and the brine evaporated, the residue treated with water to dissolve out the salt, and then incinerated and weighed; finally, the ash must be tested for iron and chalk according to the processes already given.

CHAPTER XXVII.

THE ADULTERATION OF BOTTLED FRUITS AND VEGETABLES.

DEFINITION OF ADULTERATION.

Copper or any foreign colouring matter.

An attentive examination, with the eye alone, of various samples of GREEN bottled fruits and vegetables served to raise suspicion, and to produce the impression that the method of preservation adopted by modern preservers of these articles was not quite so harmless as that originally proposed by Mr. Saddington. We felt, indeed, a strong conviction that the same means of coloration was resorted to in the case of bottled fruits and vegetables as in that of pickles. In order to determine whether this conviction was well founded or not, we instituted a series of rigorous analyses.

The extraordinary effect of copper, in heightening and rendering permanent the green colour of fruits and vegetables, is exerted upon the green contents of the cells, the chlorophylle, and hence it is the coloured portions of vegetables and fruits, as those invested by the epidermis, which are most affected by this substance. The copper used accumulates in this membrane as a salt—as an acetate, a citrate, or a malate of copper.

The presence of copper, however, in fruits and vegetables is not confined to the coloured portions; it penetrates through the whole tissue; and a considerable part of the metal used even remains diffused throughout the fluid in which the vegetable substance is contained; hence it is desirable to analyse for copper not only the preserved article itself, but also the fluid in which it is immersed.

Results of Analyses of Samples.

Thirty-four samples of different kinds of bottled fruits and vegetables were subjected to chemical analysis. From these analyses the following conclusions were deduced :—

1. That of the *thirty-three* samples of preserved fruits and vegetables, *seven were free from contamination with copper.*
2. That *twenty-seven* samples *were more or less impregnated with that metal.*
3. That *traces of copper were discovered* in *three* of the samples.
4. In *seven* of the samples *copper was present in small amount only.*
5. *Eight* samples contained it *in considerable amount.*
6. In *six* samples the metal *was present in very considerable amount.*
7. *Four* of the samples contained this poisonous impregnation *in very large quantities.*
8. That the samples of *limes contained copper*, the one in *small amount* only, the other in *amount more considerable.*
9. That the *gooseberries* contained a *considerable amount of copper, and some samples even a very large quantity.*
10. That the *rhubarb* contained an amount of copper even *more considerable, some samples being contaminated with it to a very large extent.*
11. That the *greengages* contained *a still greater quantity of copper*, the metal being frequently present *in highly dangerous amounts.*
12. In *olives* this *poisonous impregnation was in the largest amount*, although its effect in heightening the colour of the fruit is less marked than in the other cases.
13. The preserved *red fruits*, as currants, raspberries, and cherries, were *not as a rule contaminated with copper.*

The absence of copper in red fruits, and the variation of the quantity of that metal in green fruits according to the requirements in each case, afford clear evidence that this dangerous impregnation does not arise from the mere use of copper utensils, but that it is purposely introduced, the quantity being systematically adjusted in different proportions, determined by the kind of fruit to be preserved.

That this conclusion is correct is also shown by the fact, that according to the method of preparation usually pursued, the fruit or vegetable does not come in contact with copper.

The fruit or vegetable is taken directly from the baskets or sieves in which it is received from the country, and carefully packed in bottles; these are next filled up with a liquid, consisting of water holding a small quantity of alum in solution; they are then loosely corked, and submitted for a certain time to the heat of a water-bath, so as to ensure the coagulation of the vegetable albumen; they are afterwards more tightly corked, tied over with string or wire, and further secured with resin and bladder, or with a metallic capsule.

The presence of copper, then, in bottled fruits and vegetables can only be explained on the supposition that it is purposely introduced; and this is really the case.

As in the preservation of bottled fruits and vegetables there is no vinegar to act upon the copper of the vessels, the copper, usually the *sulphate*, commonly called *blue stone*, is in all cases added direct to these articles. We have the authority of a manufacturer for stating that the quantity of this powerful and poisonous substance used is often fully as much as 5 grammes to one gross of bottles of the fruit; this gives not far short of 0·04 gramme, equal to half a grain, per bottle, which is a full medicinal dose.

In some cases, where the quantity of copper is considerable, the metal becomes deposited on any metallic surface it may happen to come in contact with, in the course of a few minutes. In proof of this we will quote a paragraph from a letter written some years since by Mr. Bernays, a chemist resident in Derby, addressed to the 'Lancet.' He writes:—

'I had bought a bottle of preserved gooseberries from one of the most respectable grocers in this town, and had had its contents transferred into a pie. It struck me that the gooseberries looked fearfully green when cooked; and on eating one with a steel fork, its intense bitterness sent me in search of the sugar. After having sweetened and mashed the gooseberries with the same steel fork, I was about to convey some to my mouth, when I observed the prongs to be completely coated with a thin film of bright metallic copper. My testimony can be borne out by the evidence of three others, two of whom dined at my table.'

The colour of green fruits and vegetables is sometimes apparently heightened by a second device; the bottles in which they are enclosed are made of a highly-coloured glass; those in which French olives are preserved are of so intense a green as to impart to the fruit as seen through the bottles a deep-green colour.

As a rule, the amount of copper ordinarily present in many kinds of bottled fruits and vegetables is greater for equal quantities than in pickles, which also frequently contain that metal in large and almost poisonous quantity. Add to this the fact that while pickles are used in small quantity only, a whole bottle of preserved fruit is consumed by two or three persons at one time; hence we perceive how much more dangerous is the employment of copper in the case of fruits than in that of pickles.

The present adds another instance to the many which have already been adduced, in which manufacturers, in order to heighten the colour of articles, and as they conceive, often very erroneously, to improve their appearance, have sacrificed their flavour and quality, and have risked health, and even safety.

In the preservation of red fruits, no copper is used; but here, again, red colouring matter, as decoction of logwood, or infusion of beet-root, as well as the red aniline colours, which are almost constantly contaminated with arsenic, are not unfrequently employed, especially where the fruit is damaged or of inferior quality.

THE DETECTION OF THE ADULTERATIONS OF BOTTLED FRUITS AND VEGETABLES.

The chief adulterations of these articles are those *with salts of copper*, added for the purpose of heightening their colour. In many cases the intense green or bluish-grey colour, greatly increased when the fruit or vegetable is cooked, is sufficient to betray the presence of copper, especially to an accustomed eye.

For the detection of copper by chemical means we must have recourse to the processes described under the head of 'Pickles.'

The copper is found, as in the case of pickles, in the preserving fluid as well as in the fruit or vegetable itself.

If we desire to test the liquid, we proceed as follows:—

About 100 cc. of the juice or fluid in which the fruit or vegetable is preserved are to be measured out and placed in a test-glass; the acidity is to be slightly increased by the addition of about three drops of strong nitric acid, and a polished rod of iron placed in the fluid, and allowed to remain for about twenty-four hours. If copper is present in considerable amount, the surface of the rod, from top to bottom, becomes covered with a continuous and bright coating of that metal. If the amount of copper is less considerable, the upper half or so only of the rod receives the coating. If the quantity is very small indeed, no perceptible deposit of copper will take place.

Hence we perceive that the iron rod affords a simple and most conclusive test for copper in fruits and vegetables, when present in anything like considerable amount, and that it even serves to indicate, to a certain extent, the quantity of copper with which the juice of different samples is impregnated, as shown by the rapidity with which the deposit occurs, by the thickness of the coating, and by the extent of surface covered by it.

If we desire to analyse the fruit or vegetable, we must proceed as follows:—100 grammes of each of the fruits and vegetables are to be weighed out, placed in crucibles, and incinerated until the whole of the carbon is dissipated, the colour of the ash being carefully noted. In those cases in which the fruit or vegetable is not contaminated with copper, the residual ash is observed to be either white or greyish-white, while in those instances in which copper is present it is constantly of a pink colour, the depth varying uniformly with the amount of copper present.

When fruits or vegetable substances are carefully incinerated without being in any way disturbed, the general form of the fruit, &c., is in most cases tolerably well preserved; and it is then perceived that the pink colour is confined principally to the surface of the substance incinerated.

In those cases in which the amount of copper is but very small, the pink will be seen on the surface, only here and there, and will be of a pale tint. Where the quantity is larger, although still but small, the colour will be more general and more decided. Where it is abundant, the whole surface of the ash will be of a bright and beautiful rosy-pink hue. Lastly, when the quantity of copper present is very considerable, the residual ash will be of a deep pink colour.

Olives, when incinerated, do not leave a clean white ash, so that although the colour may be very well detected in them, it is not of so bright a pink as in other fruits; and the colour is not confined, as in most other cases, to the surface, but extends through the whole substance of the fruit.

When a portion of the juice is incinerated along with the fruit, as is usually the case, the crucibles, if copper be present, become tinted with the same rosy-pink colour observed on the surface of the ash of the fruit or vegetable incinerated. In some cases, where the amount of copper is considerable, the bottoms of the crucibles become deeply and beautifully stained of a bright and iridescent pink.

The pink colour of the ash is thus explained. In the course of incineration the acid with which the copper was combined is destroyed, the highly characteristic pink oxide alone remaining, and its presence being revealed by its peculiar colour.

The tint having been noted, the ash is next treated with some strong nitric acid. One part of the acid unfiltered solution is transferred to a test tube, and rendered strongly alkaline with ammonia. A precipitate, consisting of phosphates and other salts of the alkaline earths, is thrown down, which is allowed to settle. If copper be present the supernatant liquor will exhibit a more or less blue coloration, which is particularly perceptible when the test tube is placed over a sheet of white paper.

Another part of the solution of the ash is rendered first slightly alkaline with ammonia, the solution filtered, and then acidulated with pure acetic acid. A solution of ferrocyanide of potassium is now added; if the solution contain copper, a reddish-brown precipitate or coloration will be observed. This reaction is extremely delicate, and constitutes the best test for copper, especially when this is present in small quantities only.

For the quantitative estimation of copper, the reader is referred to the article on 'Pickles.'

CHAPTER XXVIII.

TINNED VEGETABLES.

DEFINITION OF ADULTERATION.

The presence of copper.

SEVERAL kinds of vegetables are very successfully preserved from year to year in hermetically-sealed tins, in the same manner and on the same principle as are meat, milk, and various other articles of food.

The principal kinds of vegetables thus preserved are *peas* (*petits pois*), *beans* (*haricots verts*), mixed vegetables, containing usually peas and beans, called by the French *Macédoines*, and *asparagus*.

Now, all these vegetables, with the exception of the asparagus, are very frequently coloured with copper in the same manner as are the bottled fruits and vegetables.

In this case likewise the copper is added intentionally, consisting in the addition usually of a solution of the *sulphate of copper* or *blue stone*. The quantity added is even more considerable than in the case of the articles preserved in bottles, the colour of the tinned peas and beans being often intensely and unnaturally green.

This highly objectionable practice was made known by us many years since in reports in the 'Lancet,' and although the exposures then made have led to a diminution of the practice, especially in this country, we are yet frequently called upon to analyse vegetables in tins with the result of discovering copper in the majority of cases.

Vegetables are extensively preserved in tins both in this country and abroad, where peas and beans are even cheaper than with us. The English manufacturers now less frequently add copper than they did formerly, but enormous quantities of these vegetables continue to be imported from France, notwithstanding that the use of copper in that country has been prohibited under heavy penalties, so that we believe in France it will be scarcely possible to meet with, even at restaurants and cheap dining-places, vegetables so coloured.

In most cases the detection of this adulteration is easy enough. In many instances the colour itself is sufficient to reveal its presence, the vegetables containing it presenting a deep green colour in place of the olive tint characteristic of copper-free vegetables when cooked and preserved.

For the detection of the metal chemically, both qualitatively and quantitatively, we must proceed in the manner already described under the heads of 'Bottled Fruits and Vegetables' and 'Pickles.'

The practice above exposed is undoubtedly of a highly objectionable and dangerous character, and we trust that our food analysts will not fail to exert their authority with a view to its exposure and extinction.

CHAPTER XXIX.

PRESERVES AND JELLIES AND THEIR ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any foreign fruit or substance not acknowledged in the names under which they are sold. Copper, whether added or derived from the vessels employed in their manufacture, or any foreign colouring matter.

PRESERVES and jellies are very liable to adulteration, like a great many more articles of consumption, and this in ways which would hardly be suspected by the uninitiated.

One kind of adulteration practised is to mix a cheaper with a more expensive fruit, still calling the jam by the name of the more costly constituent. Vegetable jellies are liable to the same kind of adulteration.

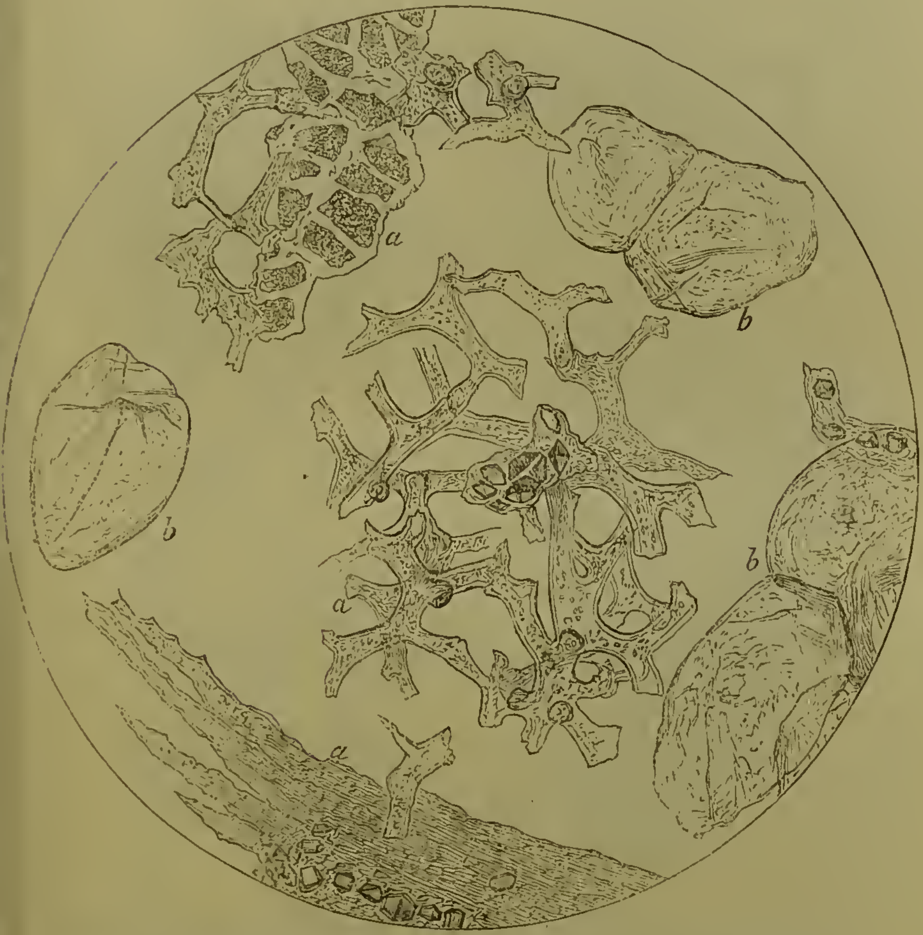
Another practice is to make use of the refuse materials derived from the preparation of vegetable jellies, as of the apple particularly, and to introduce it into jams and preserves, or to make with it and other refuse matters, including those from the manufacture of British wines, different kinds of jam, to which certain grand names and titles are given. In the same manner damaged fruits, including figs, are frequently introduced into jams. Some time back, Dr. Tidy called the attention of the City Commission of Sewers to the fact that 210 boxes of bad figs, weighing 8,000 lbs. in all, had been seized at Cox's Quay, and stated that he had reason to believe that this was only a small portion of an enormous quantity which had arrived in the docks. The figs themselves, which were rotten and maggoty, were quite unsaleable, and were used in the manufacture of jam, together with bad plums and the sweepings of fruit warehouses. The seeds, with a small quantity of raspberry jam with which the concoction was mixed, gave the so-called preserve a genuine appearance, and it was largely sold among the poor under the names of 'Family preserve,' 'Royal jam,' 'Fruit preserve,' and 'Household jam.'

Lastly, the jams of a green colour, as those of the *greengage*, *plum*, and *gooseberry*, are frequently greened or coloured by means of copper. In some instances this is purposely introduced, and in others its presence is due not to any intentional admixture, but to the use, and especially the careless employment, of copper pans in the manufacture of the jams.

One of the jams very liable to adulteration is *raspberry jam*. This is frequently mixed with a proportion of the pulp of the *gooseberry*.

Strawberry jam is liable to the same adulteration. In samples of mixed raspberry and gooseberry jam we have met with large quantities of *apple*. Again, *marmalade* is sometimes found to contain the pulp of either *apple* or *turnip* (fig. 139), but much more frequently still it contains a proportion of *apple jelly*; indeed, at one time, we believe, there was scarcely a marmalade to be obtained from the shops free from that admixture. The makers assert that this addition is not made for the

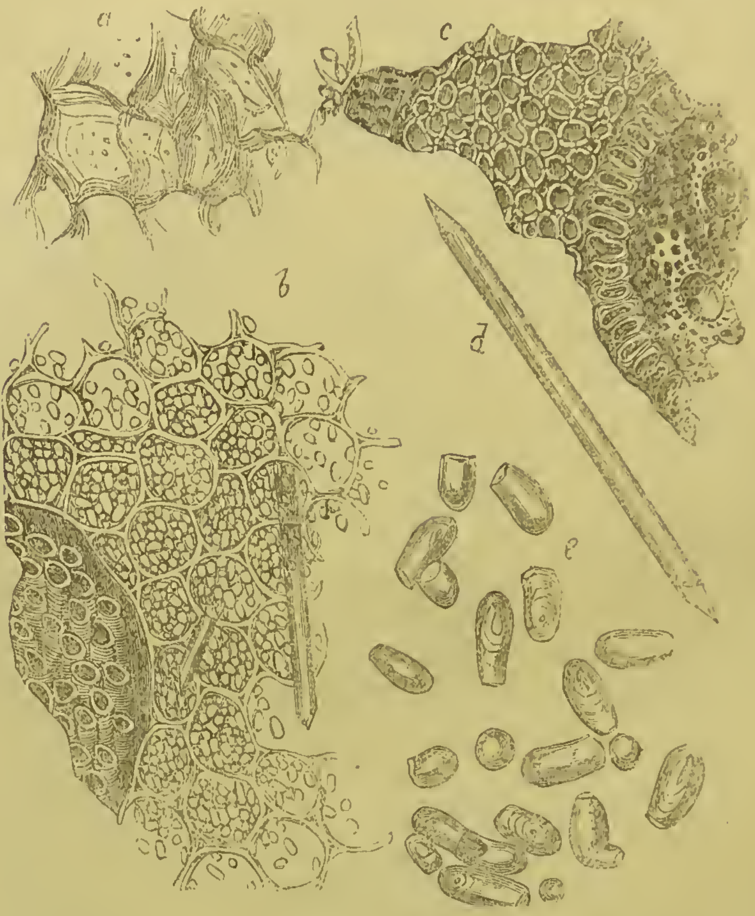
Fig. 139.



ORANGE MARMALADE, adulterated with *Apple* or *Turnip*. *a a*, tissue of orange; *b b*, cells of foreign vegetable substance. Magnified 100 diameters.

purpose of adulteration, but to stiffen the marmalade. All we can say is, that housekeepers who make their own marmalade do not find any such admixture to be requisite, and with the quality of home-made marmalade no fault can be found. We have been informed that a species of *swede* of a yellow colour is much used in the adulteration of orange marmalade. *Sweet oranges* are also sometimes employed.

Fig. 140.



ORRIS ROOT. *a*, *epidermis*; *b*, transverse section of root showing the *cells* filled with *starch*, long prismatic *crystals*, and portions of a bundle of *vessels* cut across; *c*, section of *rootlet*; *d*, *crystal*; *e*, *starch granules*. Magnified, *a*, *b*, *c*, 100, *d* 200, *e* 500 diameters.

The two principal vegetable jellies prepared are those made from the *red* and *black currant*. Now, red currant jelly in nearly all instances contains a large admixture of jelly prepared from the gooseberry, and it is probable that that of the black currant is similarly compounded. *Raspberry jelly* is said usually to consist of currant jelly to which the flavour of the raspberry has been communicated by means of *orris root* (fig. 140). *Raspberry flavouring* for sugar confectionery is made entirely of currant jelly and orris root. But organic chemistry has in these days reached such a pitch that the odour and flavour of almost any fruit is capable of being imitated. We have recently received samples of the following *artificial* fruit essences manufactured by Messrs. Langdale & Co., of Hatton Garden:—Essence of apples, pears, quince, pineapple, raspberries, strawberries, cherries, peach kernels, rum, gin, cognac, Maraschino, hops, vanilla, parsley, celery, and curry powder.

It was curious to observe how the names of certain articles were changed as soon as the late Adulteration Act came into operation. Thus it became rare to meet with a pot labelled *red currant jelly*, as this would have exposed the vendors of the mixed article to the operation of that Act, and so the name was changed to *red jelly*.

Results of Analyses of Samples.

Thirty-five samples of preserves and jellies of various kinds were subjected to chemical examination for copper with the following results:—

The *raspberry jam* analysed contained a very considerable quantity of *copper*.

The four samples of *gooseberry jam* examined all contained *copper*.

Copper, sometimes in large amount, was detected in twelve of the fourteen samples of *orange marmalade* analysed.

The nine samples of *greengage jam* were all more or less impregnated with *copper*, it being present in considerable amount in five of the samples.

The *greengages* contained in three different boxes of *crystallised fruits* all owed their deep green colour to the presence of *copper*.

The *limes* and *greengages* present in a little glass jar of fruit preserved in jelly also owed their brilliant colour to a salt of *copper*.

Copper was present in the three samples of *candied citron peel* subjected to analysis.

Thus *Copper* was detected in no less than *thirty-three* of the *thirty-five* samples of different preserves analysed: three contained *traces* only; in eleven the metal was present *in small quantity*; and in nineteen either *in considerable* or even *very large amount*.

Knowing well the powerful action of vegetable juices and also of sugar upon copper, we have long entertained the belief that copper would be very frequently detected, on analysis, in preserves, jams, and jellies, as ordinarily prepared: we must acknowledge, however, that the result of actual investigation has far exceeded our expectations, since it has proved that preserves made in copper vessels not only almost invariably contain copper, but that the metal is often present in very considerable quantities, sufficient to tint the ash of a deep pink, and to cause the solution of the ash when treated with ammonia to become of a decided and sometimes even of a deep blue colour.

But the still larger quantities of copper detected in certain of the samples of greengage jam seem to show that, as was ascertained to be the case with bottled fruits and vegetables, some greening salt of copper, of the sulphate or acetate, is really intentionally introduced for the purpose of creating an artificial viridity.

The disclosures now made afford convincing proof how improper and even dangerous it is to make preserves, as is commonly done even by ordinary housekeepers, in copper saucepans. The vessels employed for this purpose, wherever practicable, should be lined with enamel.

Although we may fairly expect to find copper in any preserved vegetable substance prepared in the ordinary manner, yet we scarcely expected to meet with that poison in those tasteful and sparkling little boxes of bonbons which at Christmas-time are displayed in shop windows so attractively; neither did we expect to find it making its way, through the citron-peel used, into our very Christmas plum-pudding.

We have repeatedly shown that the adulterators of our food do not scruple to employ, when it suits their purpose, the most deadly substances, undeterred by the serious consequences which but too frequently result from their use. Thus, it has been proved that it is no uncommon thing for them to make use of various preparations of iron, lead, copper, arsenic, mercury, &c. It is not a little remarkable that the majority of the substances are had recourse to, not on account of bulk or weight, but for the mere sake of colours, which, thus procured, are frequently in a high degree glaring and unnatural, these colours being obtained, too, at the expense of quality and flavour.

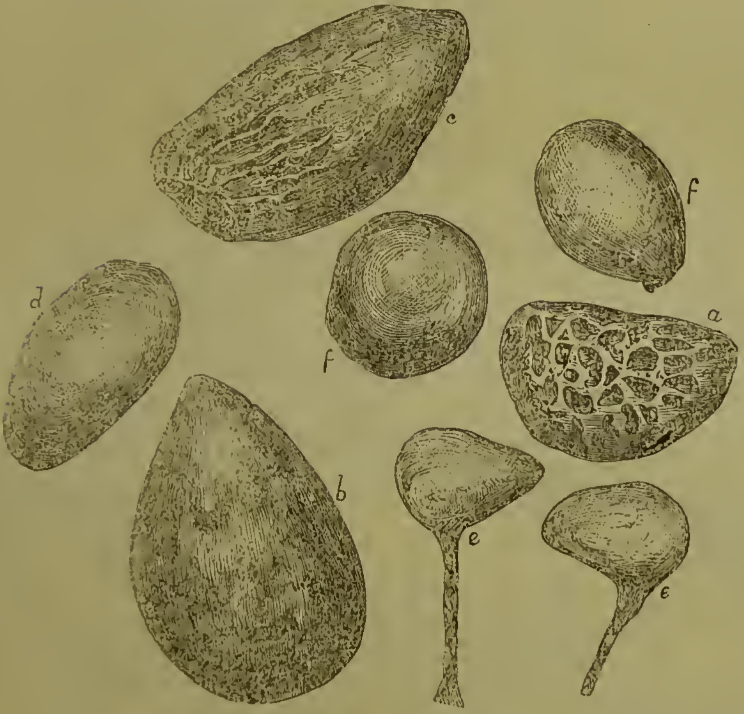
Amongst the articles which have already been treated of, and in which foreign colouring ingredients have been detected, are tea, chicory, cocoa, cayenne, mustard, pickles, bottled fruits and vegetables, tinned vegetables, potted meats, and fish. The list is, however, far from complete as yet, and on the present occasion we have added other articles.

The quantity of copper contained in jams, even in those cases in which it is perfectly certain that no intentional addition of any salt of that metal has taken place, varies very greatly. The reason of this variation in the amount depends, we believe, greatly upon the care taken in the preparation of the jams. When acids, as those of fruits, are brought in contact with a clean and bright surface of copper, no immediate or direct action takes place; the metal must first be oxidised before the acid can combine with it, the oxygen for this purpose being derived from that contained in the air, which is being constantly introduced into the jam by the stirring which takes place during its preparation. These facts show how necessary it is that the copper pans, when employed, should be kept in the brightest and cleanest state possible, and that the jam should not be allowed to remain in contact with them a moment longer than is absolutely ncessary.

THE DETECTION OF THE ADULTERATIONS OF JAMS.

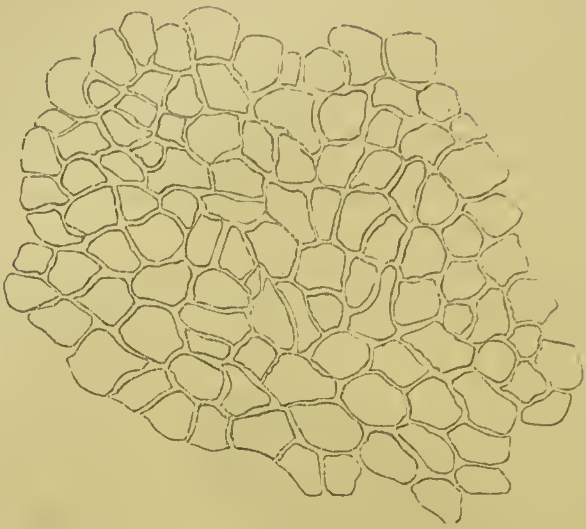
For the detection of the adulterations of jams the microscope affords, as it does in so many other cases, nearly the only means whereby the admixture of one fruit with another can be discovered. But before applying that instrument to the detection of the adulterations of jam, it is necessary that the structure of the several fruits and vegetable substances employed and the characters presented by them should be carefully studied.

Fig. 141.



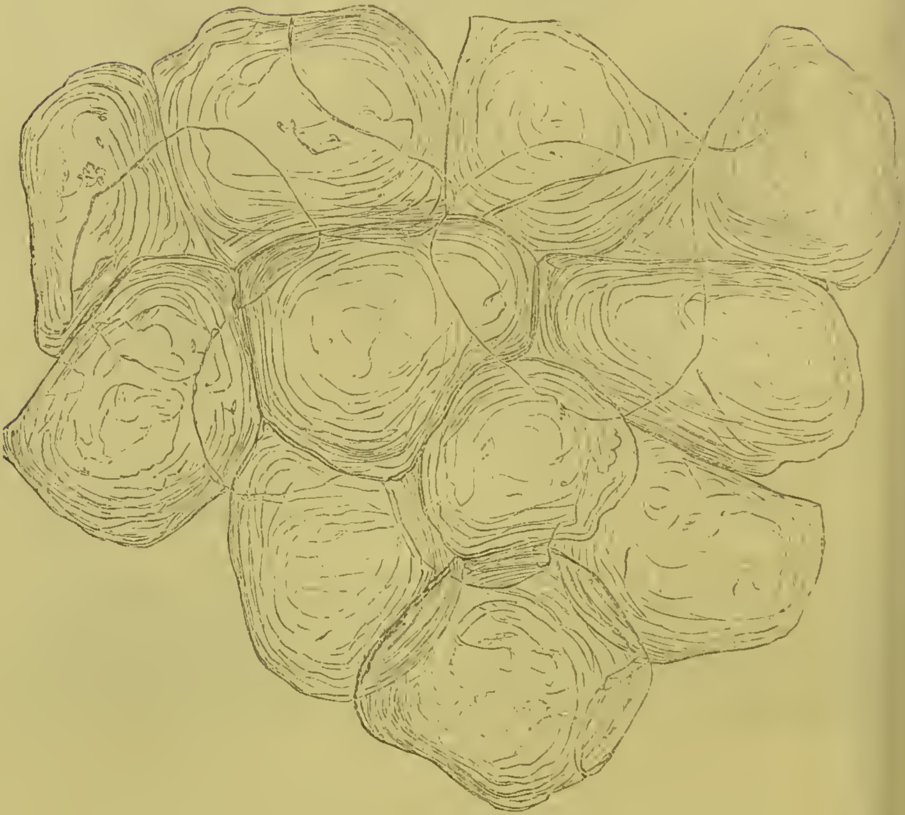
a, pip of *raspberry*; *b*, of *gooseberry*; *c*, of *white currant*; *d*, of *black currant*; *e e*, of *strawberry*; *f f*, of *fig*.

Fig. 142.



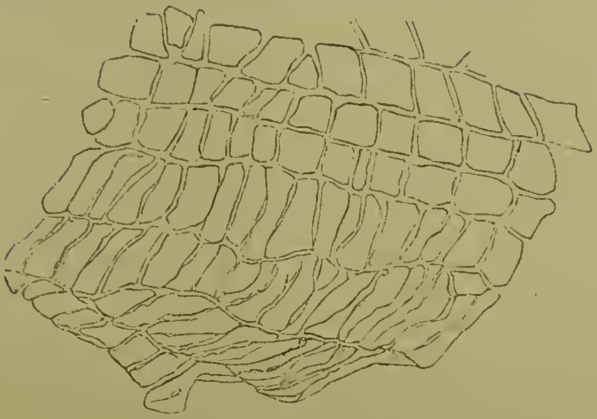
Epidermis of Apple.

Fig. 143.



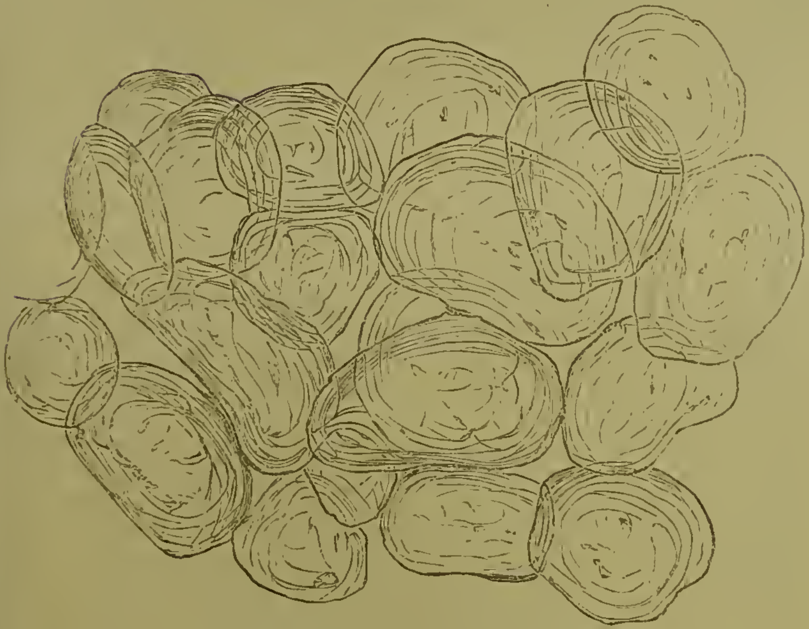
Cells of Parenchyma of Apple.

Fig. 144.



Epidermis of Turnip.

Fig. 145.



Cells of Parenchyma of Turnip.

Raspberries, strawberries, gooseberries, and currants are all distinguishable the one from the other by means of the seeds of the fruit. The differences in the characters of these are well shown in the engraving (fig. 141).

But there are other differences in the case of most of the fruits above named, either in the cuticle or the hairs with which it is clothed, or in the cells which form the pulp.

The presence of apple in jams may in general be satisfactorily discovered by means of the microscope. It is not in all cases easy to distinguish between the rounded cells of the cooked pulp of the apple and those of the turnip, but a careful examination of the jam will generally disclose in it portions of the cuticle, pips, or of the lining membrane of the cavities in which these are enclosed (figs. 142 and 143).

Again, the turnip itself presents peculiarities of structure whereby in some cases its presence may be recognised and discriminated. Thus the characters of the cuticle are very different from those of the apple, the only vegetable fruit with which it is liable to be confounded. The form of the cells composing the skin are, as will be seen from the subjoined engraving, very different, while the average size of the cells of the pulp is much smaller than that of the apple (figs. 144 and 145).

It is thus quite practicable to detect most of the adulterations of jams by admixture with other fruits and vegetables by means of the microscope, but we have as yet not indicated any method by which the proportions of the different fruits employed may be arrived at. This may be effected, however, by ascertaining the number of the pips of the different fruits present in mixed jams. Although the number of pips contained in the different fruits varies to a not inconsiderable extent, we are yet enabled by separating and counting them to form an approximate estimate of the composition of the jam. Thus the number of pips in the gooseberry varies from 25 to 35, being on an average 30; strawberry contains from 70 to 100, the average being 85; raspberries from 55 to 65, the average being 60; black currants from 35 to 45, the average being 40; and the white and red currants from 3 to 5, average 4.

By dissolving and diffusing about a tablespoonful of the jam in water the pips will be left behind. They are to be spread out on a white plate or a piece of glass, and they may then be easily distinguished by their size and other characters, including the microscopical appearances.

In reference to the detection of foreign or artificial red colouring matters, we have met with the following statements:—'With solution of carbonate of soda the artificial red colouring matter remains unchanged, while the real becomes lilac or green.'—*Food Journal.*

According to C. Puscher, *fuchsin*, rosanilin or aniline red in vegetable jellies and juices may easily be discovered by immersing in the liquid a few threads of wool or silk, which is coloured pink by fuchsin, but not by the colouring matters proper to the jellies.

According to H. Hager, the genuine syrup or jelly, when mixed with nitric acid containing 25 per cent. of acid, remains red, while artificially coloured syrup turns yellow. The genuine syrup, mixed with an equal volume of a solution of potash or ammonia of 10 per cent., turns violet, with a tint of green, blue-green or reddish-green, while the artificially coloured article turns, first pink, and after some time is quite decolorised.

With an equal volume of soda solution, the genuine article is turned lilac or green, while the artificially coloured syrup is not, or only very little changed.

Lastly, with an equal volume of a solution of neutral acetate of lead in the first case a bluish green or greyish green, and after boiling an olive green mixture is produced, while the artificial colouring matter is not essentially changed.

The methods for the detection and estimation of copper have already been more than once fully described.

CHAPTER XXX.

MUSTARD AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any foreign substance whatever, either vegetable or mineral; the mixtures now so frequently sold as mustard to be named and sold as mixtures.

The subjoined particulars, in reference to the manufacture of mustard, as furnished by a manufacturer, are given by Pereira:—

'The seeds of both black and white mustard are first crushed between rollers, and then pounded in mortars. The pounded seeds are then sifted. The residue in the sieve is called *dressings*, or *siftings*; what passes through is *impure flour of mustard*. The latter, by a second sifting, yields *pure flour of mustard*, and a second quantity of dressings. By pressure the dressings yield a fixed oil, which is used for mixing with rape and other oils.'

THE COMPOSITION OF MUSTARD.

The mustard of commerce when pure and genuine consists usually of a mixture in different proportions of the farina, with more or less of the husk of the seeds of brown and white mustard. Sometimes it is made wholly from the brown seed, and at others the farina of the white mustard seed is the principal constituent.

Of these seeds no very complete quantitative analyses have as yet been made, although many highly important particulars have been ascertained respecting their composition; thus, black or brown mustard, as it is now generally named, consists for the most part of *fixed oil*, *myronic acid*, $C_{10}H_{19}NS_2O_{10}$, which is combined with potash, forming a *myronate of potash*, and which acid is converted into the volatile oil of mustard or *sulphocyanide of allyl*, C_4H_5NS, $\left.\begin{array}{c}CN\\C_3H_5\end{array}\right\}S$, through the agency of the *myrosin*, another constituent of brown mustard, when the two are brought into contact through the medium of water; *vegetable albumen*, a *bitter principle*, a little *gum* and *sugar*, a *peculiar green substance*, *cellulose*, and *mineral matter*.

White mustard differs essentially in its composition from brown; it also contains *fixed oil*, but in lieu of myronic acid, convertible as described into the volatile oil of mustard, it contains a non-volatile, bitter, and acrid salt, termed *sulphocyanide of sinapine* ($C_{17}H_{24}N_2SO_5$, or $C_{16}H_{23}NO_5$, CNHS), *myrosin*, *gum*, *cellulose*, and *mineral matter*.

Now it is on the volatile oil and the acrid and somewhat bitter salt that the pungency and acridity of mustard depend, and hence we see a strong reason why in the mustards of commerce the farina of the two species should be blended together: of the two active principles the volatile oil is by far the more important, and hence the seed of the brown mustard possesses the greatest commercial value. It should be stated that Henrie and Garot affirm that brown mustard contains the acrid principle as well as the white; this statement we have been able to verify, as shown specially by the action of nitric acid, caustic potash, and ferric chloride on the alcoholic extract.

The acrid principle of white mustard appears to possess but little stability, and although it is stated by v. Babo to bear a temperature of 130° C., we find that it is readily affected by heat, and that it is not safe to evaporate the alcoholic solution containing it at a higher temperature than about 30° C. If subjected to a much higher temperature it quickly loses its acridity, and acquires a bitter caramel-like taste.

Of neither brown nor white mustard had any percentage analysis been given until those made and published by ourselves in an article on mustard and its adulterations, in 'Food, Water, and Air,' for February 1874, and in the few cases in which the quantities of any of the constituents are stated they vary greatly, according to different observers. Thus, according to Pereira, the *fixed oil* forms about 28 per cent. of the seeds of black mustard, while Watts puts the yield at 18 per cent. only, but white mustard seed, he says, furnishes 36 per cent. The *volatile oil* amounts to 0·20 per cent. according to Boutron and Robiquet; 0·55 per cent. according to Aschoff; and 0·50 per cent. according to Wittstock; all which quantities are much below the mark, as will be seen hereafter. Now, as will be shown presently, there is little or no difference in the amount of fixed oil furnished by the two descriptions of mustard—that obtained by me from the farina of brown mustard reaching 35·701 per cent., and that from the white mustard 35·768 per cent. Again, it is shown by the analyses given below that the volatile oil occurs in much larger quantities than those enumerated above, the amount which we have obtained from one sample being no less than 1·271 per cent.

Of both brown and white mustard we append the following original percentage analyses, first published in the article referred to:—

Brown Mustard Farina.

Water	4·845
Fixed oil	35·701
Myronic acid	4·840
Myrosin and albumen	29·536
Acrid salt	3·588
Cellulose	16·765
Ash	4·725
	100·000
Volatile oil	1·271
Nitrogen	5·068
Sulphur	1·413

The oil extracted by ether from the brown seed is of a bright and beautiful emerald green colour, owing to the presence of the peculiar green principle, described as one of its constituents. So deep and remarkable is the colour of the oil that it would be easy, by means of a graduated scale of tints, to determine with very tolerable certainty the percentage of brown mustard contained in any sample of mixed mustard.

White Mustard Farina.

Water	5·360
Fixed oil	35·768
Acrid salt	10·983
Myrosin and albumen	27·484
Cellulose	16·295
Ash	4·110
	100·000
Nitrogen	5·285
Sulphur	1·224

These analyses, whether regarded from a scientific or practical point of view, are possessed of much interest.

The small quantity of sugar found in mustard would, from the method of analysis pursued, be included under the bitter principle, and the gum with the cellulose.

Myronic acid occurs as *myronate of potash* in the seed of sinapis nigra. Myronic acid is a strongly acid liquid, soluble in water and alcohol, but insoluble in ether. Myronate of potash is soluble in water and alcohol and crystallises in rhombic prisms. It has a bitter taste and neutral reaction. It undergoes a most remarkable change under the influence of the nitrogenous substance contained in mustard seed, myrosin. It decomposes into oil of mustard, or sulphocyanide of allyl, glucose, and acid sulphate of potassium, $C_{10}H_{18}KNS_2O_{10} = C_4H_5NS + C_6H_{12}O_6 + KHSO_4$.

Oil of mustard is not ready contained in the seed, but is formed by the decomposition of the myronate of potash. It possesses the odour of mustard in so high a degree, that the smallest quantity of vapour excites tears. It blisters the skin, boils at 148° C. and has a specific gravity of 1·015 at 20°. In contact with aqueous ammonia it takes up one molecule of ammonia and forms a crystalline, non-volatile substance, *thiosinnamine*, C_4H_5NS, NH_3.

Myrosin is the name of the albuminous substance contained in mustard. It has the closest resemblance to the other albuminous bodies. It is coagulated by heat and by alcohol. If coagulated it no longer effects the decomposition of the myronates.

Sulphocyanide of sinapin occurs both in white and black mustard, but in white in the largest proportion. It crystallises in white needles or glassy prisms. It is neutral, inodorous, of a bitter and burning taste. Fusing point 130° C. It is soluble in water and alcohol.

These being the principal and characteristic constituents of both black and white mustard, we now proceed to describe the analysis of mustard.

THE ANALYSIS OF MUSTARD.

The substances with which we shall have to deal are—*water*, *fixed oil*, *myronic acid*, *myrosin* or *albumen*, *sinapin*, *cellulose* and *mineral matter*.

Estimation of water, fatty and mineral matters.—We have already so often described the processes for the estimation of these substances, that we refrain from doing so again.

Estimation of the myronic acid.—Myronate of potash decomposes under the influence of the nitrogenous matter contained in brown mustard into volatile oil, glucose, and acid sulphate of potash; the quantity of each of these products of decomposition gives therefore by simple calculation the quantity of the myronic acid. 100 parts of this acid yield 23·85 parts of volatile oil. From 40 to 50 grammes of the mustard farina are placed in a flask of about ½ litre capacity; 250 cc. of tepid water are poured over it, the flask closed with a cork, and the whole is well shaken. After twenty-four hours' standing, the flask is connected with a Liebig condenser, and its contents are heated to boiling. Into the receiver 30 cc. of strong ammonia are poured and the end of the condenser is dipped below the surface of the liquid. Water and the volatile oil pass over, the latter at first floating in the shape of oily drops on the surface of the liquid, which soon sink to the bottom, especially when the liquid is gently agitated. When the distillation is finished, which is the case when no more oil globules pass over, the receiver is closed with a cork and allowed to stand for twenty-four hours. At the end of that time all the oil is dissolved and is now contained in the liquid in the form of thiosinnamin. This solution is evaporated on the water-bath in a weighed platinum basin, the residue dried and weighed. The quantity of thiosinnamin obtained, minus one molecule of ammonia, represents the amount of the volatile oil.

Estimation of the myrosin, or albumen, and of the sulphocyanide of sinapin.—The total amounts of nitrogen and sulphur contained in the mustard are next ascertained. The former by combustion with soda-lime in the well-known manner, the latter by deflagration of the mustard and oxidation of its sulphur in a mixture of nitrate of soda and carbonate of potash. The fused mass is dissolved in water or dilute acid, and the sulphuric acid contained in the solution is estimated by means of chloride of barium. From these data the amounts of the myrosin and of the sulphocyanide of sinapin, the acrid principle, are thus calculated; as much sulphur and nitrogen are first deducted from the totals of these substances obtained as is contained in the quantity of myronic acid previously determined. Next, the whole of the remaining sulphur and as much of the nitrogen as is required are then calculated into the acrid principle; lastly, the surplus nitrogen is calculated into myrosin, which has the same formula as vegetable albumen. But now, having got at approximately the amounts of the acrid principle and of the myrosin, a further calculation has to be made, since myrosin contains about 1 per cent. of sulphur. This has to be deducted from the total acrid principle, a corresponding quantity of nitrogen being in its turn calculated into myrosin. By those acquainted with algebra, it will be readily perceived that a more precise calculation may be made, but the results would not, even then, differ to any practical extent.

ANALYSES OF SAMPLES OF GENUINE MUSTARD OF DIFFERENT QUALITIES.

Having given the analyses of the farinas of brown and white mustard, we will now proceed to state those of certain qualities of mustard distinguished by different names, and consisting of mixtures in different proportions of black and white mustard:—

Genuine Mustard.

Water	5·702
Fixed oil	36·491
Myronic acid	2·704
Myrosin and albumen . .	31·686
Acrid salt and bitter principle	5·714
Cellulose	13·373
Ash	4·330
	100·000
Oil of mustard	0·710
Nitrogen	5·341
Sulphur	1·308

Genuine double superfine.

Water	5·163
Fixed oil	35·942
Myronic acid	2·212
Myrosin	27·360
Acrid salt and bitter principle	9·085
Cellulose	15·574
Ash	4·664
	100·000
Volatile oil	0·581
Nitrogen	5·047
Sulphur	1·424

Genuine superfine.

Water	5·592
Fixed oil	34·714
Myronic acid	1·971
Myrosin	31·021
Acrid salt and bitter principle	7·098
Cellulose	15·284
Ash	4·320
	100·000
Volatile oil	0·518
Nitrogen	5·460
Sulphur	1·246

Genuine fine.

Water	5·683
Fixed oil	35·241
Myronic acid	0·922
Myrosin	27·897
Acrid salt and bitter principle	10·062
Cellulose	15·542
Ash	4·653
	100·000
Volatile oil	0·242
Nitrogen	5·159
Sulphur	1·297

Pure.

Water	5·084
Fixed oil	33·979
Myronic acid	0·963
Myrosin	27·616
Acrid salt and bitter principle	11·258
Cellulose	16·807
Ash	4·293
	100·000
Volatile oil	0·253
Nitrogen	5·208
Sulphur	1·403

Household Mustard.

Water	5·294
Fixed oil	36·748
Myronic acid	1·725
Acrid principle	8·751
Myrosin	27·475
Ash	3·690
Cellulose	16·317
	100·000
Volatile oil	0·453
Nitrogen	5·026
Sulphur	1·314

Now the six analyses above given prove two things—first, that all the samples are genuine; this is shown by the quantities of fixed oil, nitrogen, and sulphur obtained; and that they consist of mixtures of the two mustards in different proportions, the higher qualities containing larger proportions of the brown mustard; that this is so is demonstrated by the different quantities of volatile oil obtained.

ANALYSES OF MIXED OR ADULTERATED MUSTARDS.

We shall in the next place proceed to give the analyses of some mixed or adulterated mustards of different qualities, and distinguished by various names. The analyses were conducted as in the case of the genuine mustards, the only difference being that an allowance was made for the nitrogen of the wheat flour:—

Double superfine.

Water	4·941
Fixed oil	27·522
Myronic acid . . .	3·136
Acrid principle . . .	1·851
Myrosin	23·155
Wheat flour and turmeric .	22·986
Cellulose	13·055
Ash	3·354
	100·000
Volatile oil	0·850
Nitrogen	4·242
Sulphur	0·945

Fine.

Water	6·510
Fixed oil	23·160
Myronic acid . . .	1·359
Acrid principle . . .	5·808
Myrosin	19·501
Wheat flour and turmeric .	27·204
Cellulose	12·841
Ash	3·617
	100·000
Volatile oil	0·357
Nitrogen	3·850
Sulphur	0·959

Superior.

Water	4·973
Fixed oil	25·172
Myronic acid . . .	1·200
Acrid principle . . .	4·313
Myrosin	23·244
Wheat flour and turmeric .	25·820
Cellulose	11·495
Ash	3·783
	100·000
Volatile oil	0·315
Nitrogen	4·074
Sulphur	1·057

To the above analyses we will now add those of some samples of mixed mustard purchased in the loose state at some shops in London:—

Suerts.

Water	8·943
Fixed oil	23·876
Myronic acid . . .	1·565
Acrid principle . . .	6·451
Myrosin	14·484
Wheat flour and turmeric .	33·815
Cellulose	7·076
Ash	3·790
	100·000
Volatile oil	0·411
Nitrogen	3·339
Sulphur	0·997

Alexander.

Water	8·347
Fixed oil	29·604
Myronic acid . . .	1·915
Acrid principle . . .	3·150
Myrosin	13·893
Wheat flour and turmeric .	30·514
Cellulose	8·987
Ash	3·590
	100·000
Volatile oil	0·503
Nitrogen	3·164
Sulphur	0·899

Lindsey.

Water	8·870
Fixed oil	21·536
Myronic acid	0·985
Acrid principle	6·210
Myrosin	21·760
Wheat flour and turmeric	25·208
Cellulose	11·688
Ash	3·743
	100·000
Volatile oil	0·259
Nitrogen	4·304
Sulphur	0·938

Gilbert.

Water	6·280
Fixed oil	22·060
Myronic acid	1·127
Acrid principle	4·253
Myrosin	15·302
Wheat flour and turmeric	38·820
Cellulose	8·405
Ash	3·753
	100·000
Volatile oil	0·296
Nitrogen	3·464
Sulphur	0·817

Goodman.

Water	8·950
Fixed oil	26 896
Myronic acid	1·816
Acrid principle	5·186
Myrosin	15·577
Wheat flour	30·559
Cellulose	7·276
Ash	3·740
	100·000
Volatile oil	0·477
Nitrogen	3·374
Sulphur	0·941

Clark.

Water	9·582
Fixed oil	18·314
Myronic acid	0·385
Acrid principle	7·026
Myrosin	20·818
Wheat flour	32·805
Cellulose	8·653
Ash	2·417
	100·000
Volatile oil	0·101
Nitrogen	3·325
Sulphur	0·905

From an examination of the foregoing analyses it is apparent that genuine *brown* mustard should contain about 36 per cent. of fixed oil, at least 1 per cent. of volatile oil of mustard, about 4 per cent. of acrid principle, and that it should furnish about 1·5 per cent. of sulphur and 5 per cent. of nitrogen; that genuine *white* mustard should yield about the same amount of fixed oil, over 10 per cent. of acrid principle, and nearly the same amount of nitrogen and sulphur as the black; that the composition of genuine mustards, which are made up in various proportions of brown and white mustard-seed, differs according to the quantities of each kind present, the relative proportions being determinable by analysis with considerable precision; that in the mixed or adulterated mustards the proportions of fixed and volatile oil, of nitrogen and sulphur are all much reduced, according to the extent of the admixtures, these consisting in the mustards now reported upon in all cases of wheat flour and turmeric. Thus the fixed oil was reduced in one of the samples from 36 per cent., the normal amount, to about one-half, or 18 per cent.; the volatile oil to 0·1 per cent.; and the nitrogen to 3·32 per cent.; while in another sample the sulphur was as low as 0·81 per cent. The amount of wheat flour and turmeric varied from 22·91 per cent. to 38·82 per cent., that is to say, from one-fourth to one-third of the article.

It has already been pointed out that the turmeric is added to the mustard simply for the sake of its colour, and to cover and conceal the addition of the wheat flour. In favour of this addition it is believed that not a single reason can be adduced, except possibly that its use allows of the addition of a larger quantity of brown mustard-seed than could otherwise be employed at a given price, and that thus the public gain an advantage, wheat flour being, of course, cheaper than white mustard, which again is less costly than brown mustard; but this difference in the cost must really be very inconsiderable, and if obtained at the expense of the purity of the article, the practice should be abandoned. At all events, it is wrong and misleading to call these mixed articles by the name of mustard. By making mustard in all cases either entirely of the brown seed or of admixtures of the brown and white seed, a wide range in the qualities and prices of mustard is obtained, and the mustard in which the white seed greatly predominates can be sold, we know, at a very low price. We trust, therefore, that the time has now arrived for the abandonment of the use of wheat flour and turmeric in the manufacture of mustard, and that, if the sale of the mixtures still be allowed, the law will continue to render it compulsory that the mixed articles should be sold only as mixtures, and not under the name of mustard simply. We even regard the manufacture of several varieties and qualities of the same article, as mustard for example, a very great evil, and the public suffers in pocket to a large extent thereby, the lowest qualities of these mixtures being constantly sold at the price of the higher, and especially is this the case in poor neighbourhoods. This is an evil which, so far, has been but little dwelt upon, but it is nevertheless most serious, and it vitiates the trade in the articles mustard, cocoa, and vinegar.

STRUCTURE OF MUSTARD SEED.

Every entire seed consists of two parts, the husk and the seed proper.

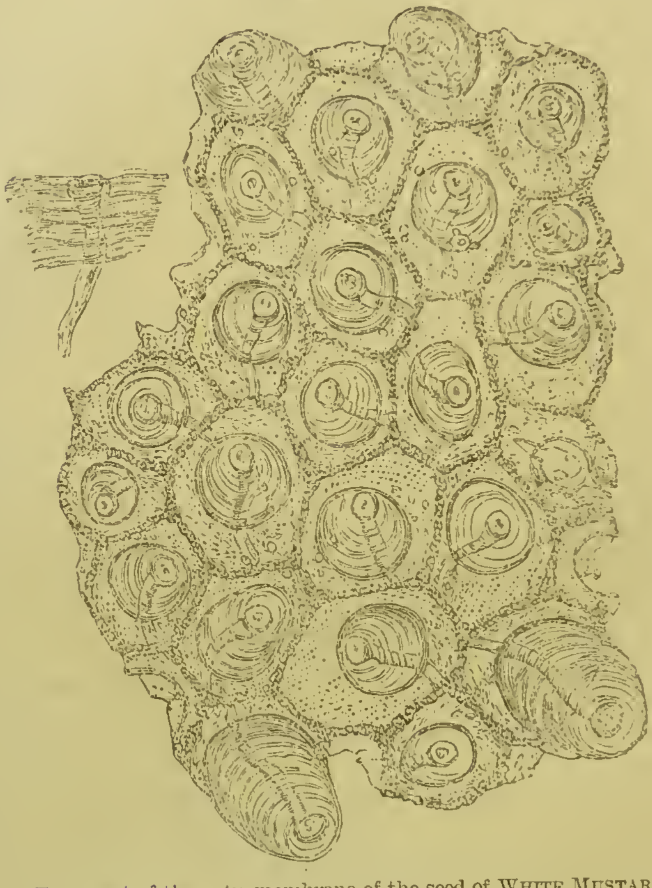
The husk of *white mustard seed* is constituted of three distinct membranes.

The *outer* membrane is transparent, and mucilaginous; it consists of a layer formed apparently of two different kinds of cells of large size and very peculiar structure; those of the first kind are of an hexagonal figure, and united by their edges so as to form a distinct membrane, the centre of each cell being perforated; the cells of the second kind occupy the apertures which exist in the previously described cells, and they are themselves traversed by a somewhat funnel-shaped tube, which appears to terminate on the surface of the seed; immersed in water, these cells swell up to several times their original volume, occasion the rupture of the hexagonal cells, and become themselves much wrinkled or corrugated, the extremity of the tubes in some cases being seen protruding from the proximate termination of the cells.

It is possible, however, that what are here described as two different kinds of cells really form distinct parts of the same cells (fig. 146).

It has been noticed that when white mustard seeds are digested in water, a thick mucilaginous liquid is obtained; the source of the mucilage does not appear to have been pointed out; it is certainly, however, derived from the cells forming the tissue above described.

Fig. 146.



Fragment of the *outer* membrane of the seed of WHITE MUSTARD. Magnified 220 diameters.

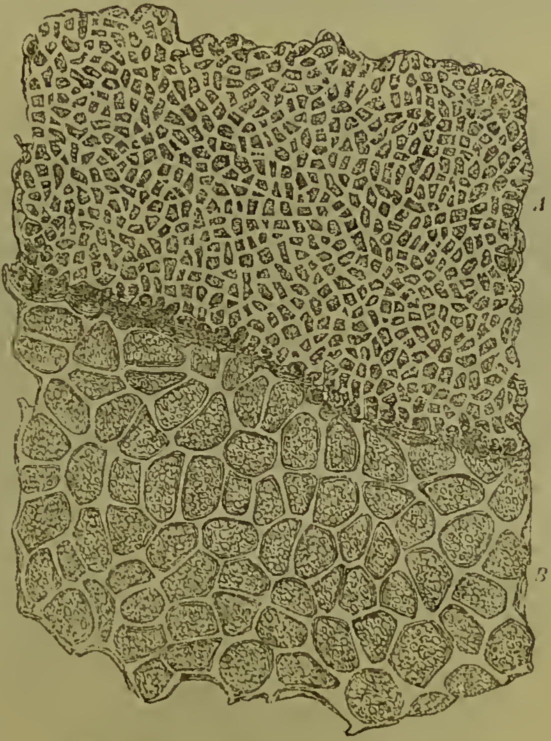
The *middle* tunic consists of a single layer of very minute cells, of an angular form; it is in the cavities of these that the chief parts of the colouring matter possessed by the husk is seated.

The *inner* membrane also consists of a single layer of angular cells, which, however, are several times larger than those constituting the middle tunic (fig. 147).

The *seed* itself is of a bright yellow colour, and of a soft, waxy consistence, depending upon the quantity of oil it contains; it consists of innumerable very minute cells, in the cavities of which the oil and other active principles are contained (fig. 148).

Notwithstanding the terms 'flour' and 'farina' of mustard commonly employed, ripe mustard seed does not contain a single starch granule, as may be ascertained by means of iodine and the microscope.

Fig. 147.



Fragments of the *middle* and *inner* tunics of *White* Mustard seed, the former covering and lying upon a part of the latter. Magnified 220 diameters. *A.* Portion of the *middle* tunic. *B.* A fragment of the *inner* tunic, showing the structure of that membrane.

In *black mustard,* the outer membrane of the seed consists only of the large hexagonal transparent cells disposed in two or three layers, and not perforated in the centre like those of white mustard; the other structures resemble those of white mustard (fig. 149).

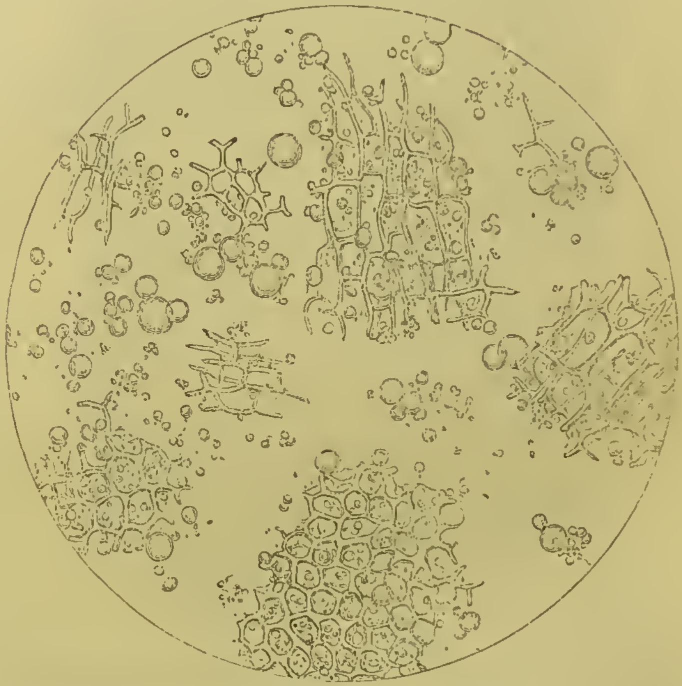
THE ADULTERATIONS OF MUSTARD.

The ordinary adulterations of mustard are with *wheat flour* and *turmeric,* the employment of the first-named article necessitating the use of the other to restore or bring up the colour to the original standard.

We have already recorded the results of many quantitative analyses of mustard, both genuine and adulterated. The results of the examination of 42 samples of mustard which were purchased in the metropolis some time back proved the whole of them to be adulterated and to consist of mixtures, in various proportions, of *wheat flour*, *turmeric*, and *mustard*.

Other adulterations sometimes practised are those with *Cayenne pepper*, *ginger*, *Sinapis arvensis*, or *charlock*, *potato flour*, *ground rice*, *silicate of alumina or clay*, *plaster of Paris*, and *chromate of lead*. The pepper is used to impart pungency to it when it has been otherwise adulterated; the clay and most of the other mineral substances for bulk and weight; and the chromate of lead to restore the colour when reduced by other adulterations.

Fig. 148.

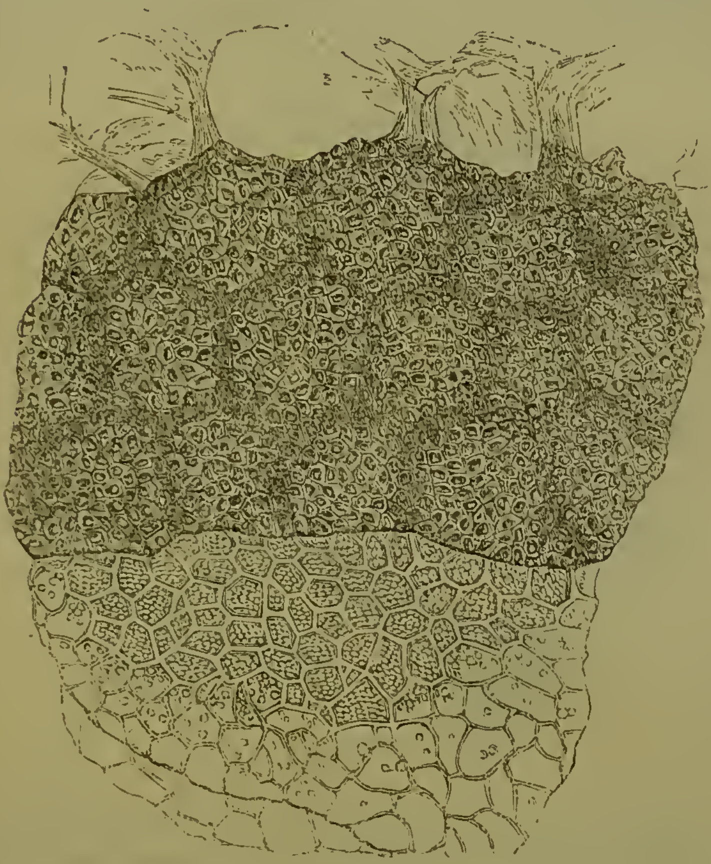


Sample of *genuine ground* White Mustard. Drawn with the Camera Lucida, and magnified 220 diameters.

Mr. Warington stated, in his evidence before the Parliamentary Committee on Adulteration in 1855, that some of the samples of mustard which he examined contained from 20 to 30 per cent. of inorganic matter, chiefly sulphate of lime; the genuine mustard when burned yielding from 4½ to 6½ per cent. of residue.

Mr. Gay, formerly a mustard and chicory manufacturer, and afterwards Superintendent of the Mustard Department in Her Majesty's Victualling Yard at Deptford, furnished the Committee above named with, amongst other information, the following respecting the adulteration of mustard. He stated:—

Fig. 149.



Husk of Black Mustard *seed*. Magnified 220 diameters.

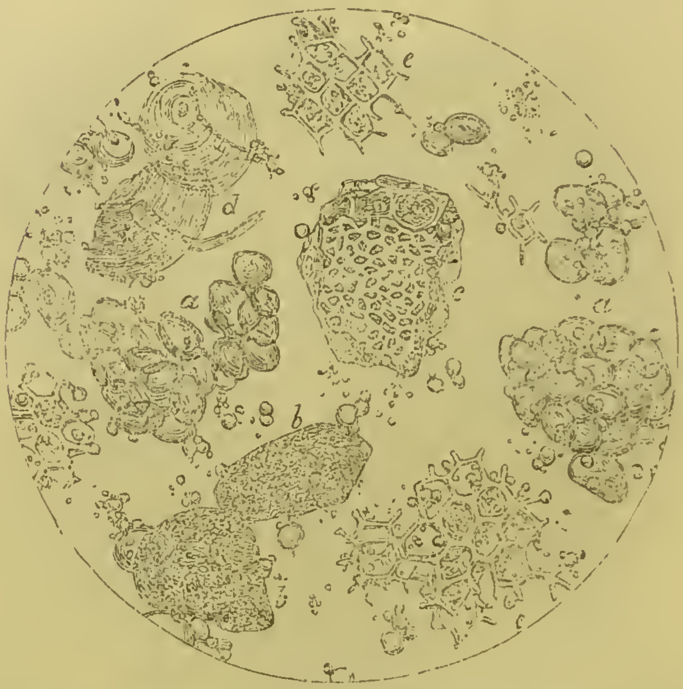
'I believe very few scruple to use wheaten flour, turmeric, and Cayenne pepper. The adulterants I used were flour, turmeric, Cayenne pepper, and *ginger*.

'But farina is also used, and *potato starch* is used to a very great extent; and now, I am sorry to say, what one of the witnesses called terra alba, or plaster of Paris. I have had some samples in my office in the mustard department since I have been in my present situation, from which I have extracted 5 ounces of gypsum in the pound; from another sample I got 5 ounces of *rice* and wheaten flour. I have seen more than 50 per cent. of gypsum in mustard.'

With regard to the adulteration of mustard with charlock, Mr. Gay remarks, 'When mustard seed is worth 20*s.* per bushel, and charlock about 6*s.* or 8*s.* a bushel, it is worth buying.'

It is also alleged that *pea flour*, *radish* and *rape seed*, *linseed meal*, and *yellow ochre* have been employed in the adulteration of mustard.

Fig. 150.



This engraving represents the articles detected in a sample of so-called '*double superfine* MUSTARD': *a a*, *wheaten flour*; *b b*, cells of *turmeric powder*; *c*, portion of *husk of black mustard*; *d*, cells of outer tunic of *white mustard seed*; *e e*, fragments of the *seed* itself.

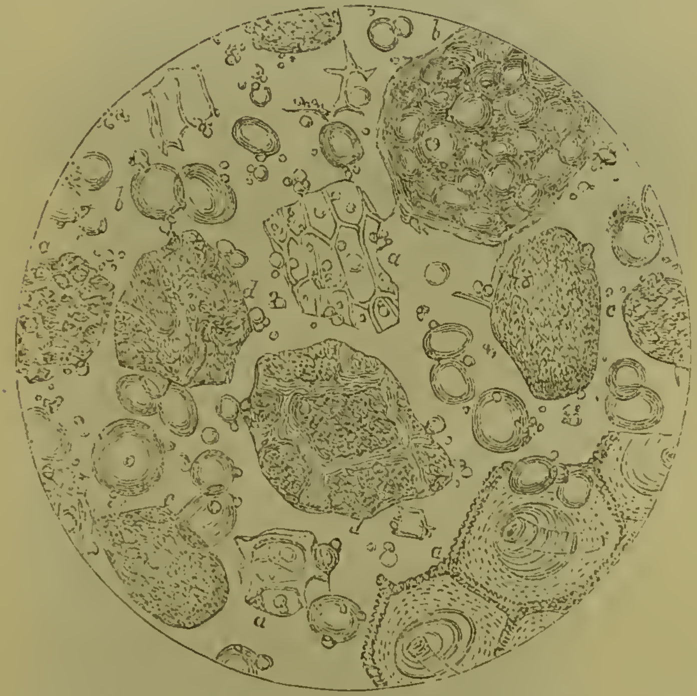
No less than four different qualities of mustard are supplied by the mustard manufacturer, under the name of 'Seconds,' 'Fine,' 'Superfine,' and 'Double Superfine;' the chief difference between these articles is that the lower the quality the larger the proportion of wheat flour and turmeric which they contain.

The practice of making so many different qualities of mustard is open to much objection, since it gives the unscrupulous dealer the greatest scope for imposition. The poor man buys his mustard by the ounce, and for this he usually pays 1*d.*, receiving in return seconds, fine, or superfine mustard, according to the conscience of the vendor.

It can now be understood how it happens that some of the mixtures which we buy for mustard scarcely possess the flavour of that article, and how, when used for poultices, they produce little or no effect, a matter oftentimes of vital consequence.

Doubtless we shall be told by the mustard manufacturer that genuine mustard is a very unpalatable thing, that it is bitter to the taste, and not pleasant to look at; but the answer to this is that the article mustard is not always made according to one receipt, and that there exist, even in England, a few manufacturers who make and sell only genuine mustard, and that the demand for genuine mustard has of late undergone a very great extension. In fact, ere long we believe but little else than the genuine article will be manufactured and sold.

Fig. 151.



MUSTARD, *a a*; adulterated with *b b*, *wheat flour*; *c c*, *turmeric*; and *d d*, *Cayenne*. Magnified 225 diameters.

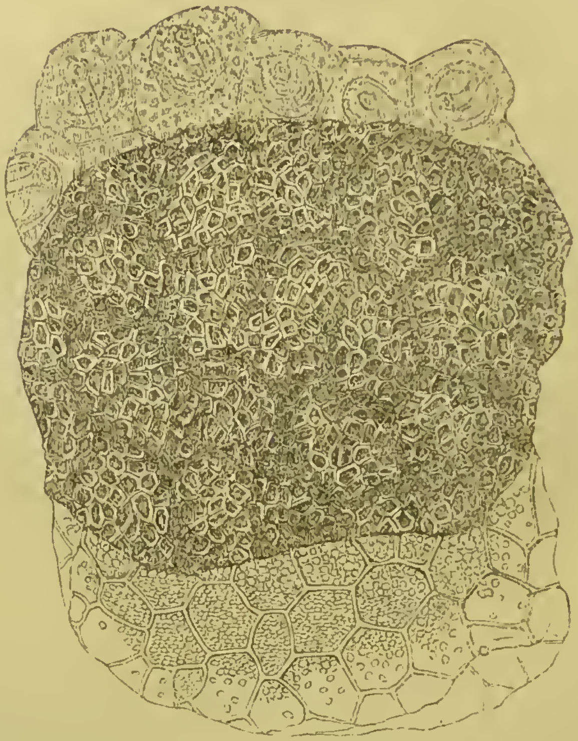
THE DETECTION OF THE ADULTERATIONS OF MUSTARD.

The detection of the organic adulterations.—The detection of the ordinary adulterations of mustard is effected very readily by means of the microscope. The characters of *wheat flour* are described and figured at p. 280, and of *turmeric* under the head of that article.

The adulterations by the other vegetable substances referred to are also discoverable with the microscope. Descriptions and figures of *pod pepper* will be found under the head of 'Cayenne,' and of *linseed meal* under that of 'Pepper.'

The presence of turmeric is also discovered by adding strong ammonia to a small quantity of the mustard, causing it to become of an orange red colour if that substance is present. This is a very simple and efficient test. The characters of mustard, adulterated with wheat flour, turmeric, and Cayenne, are exhibited in figs. 150 and 151.

Fig. 152.



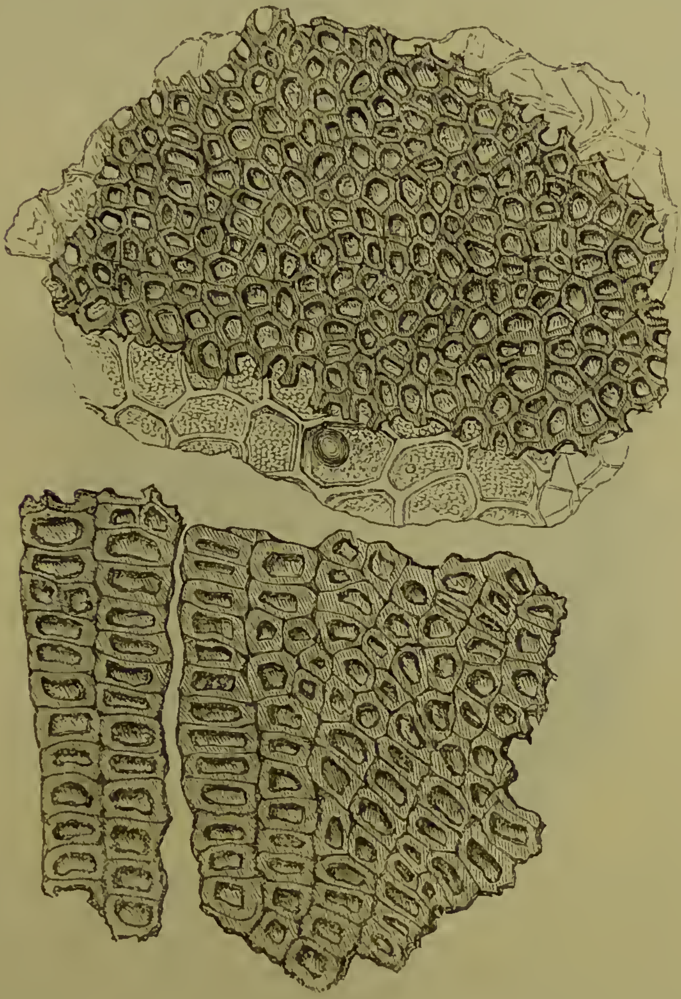
Husk of CHARLOCK *Seed, Sinapis arvensis.* Magnified 220 diameters.

On one occasion we succeeded in detecting by the microscope *turmeric* in a sample of mustard when added in the minute proportion of two ounces to fifty-six pounds of seed, or one part of turmeric to 448 parts of mustard.

As there is good reason to believe that the seeds of *charlock* and *rape* are sometimes employed in the adulteration of mustard, we append figures and descriptions of the husks of those seeds.

Structure of Sinapis arvensis, or Charlock.—The husk of this seed resembles in colour very closely black mustard, from which, however, on a careful examination, it may be discriminated by means of the microscope, notwithstanding the statement of Mr. Gay, made before the Parliamentary Committee, 'that no analytical chemist

Fig. 153.

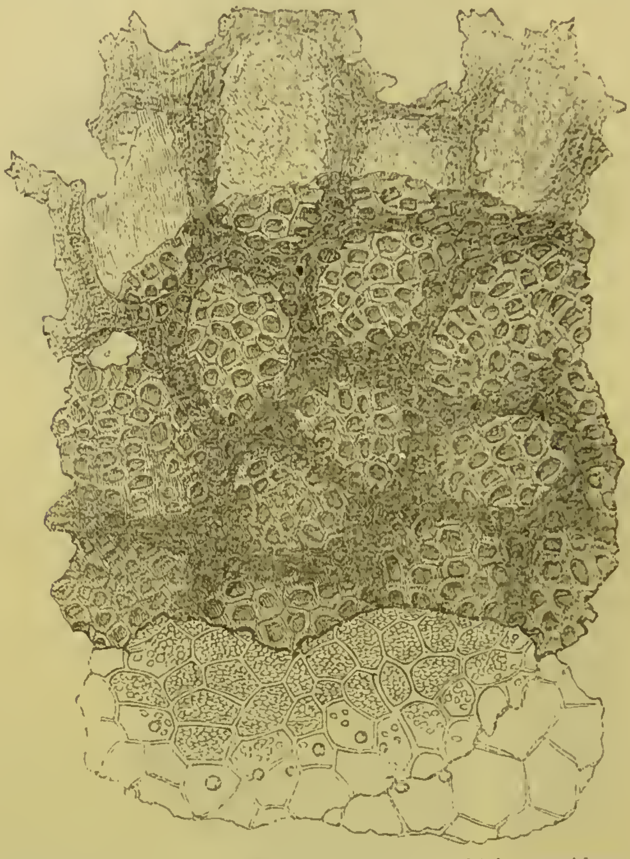


Husk of RAPE *Seed.* Magnified 220 diameters.

could detect charlock seed mixed with mustard, even with the microscope.'

While it agrees in colour with the husk of black mustard, it approaches in structure nearer that of white mustard, from which, however, it may be distinguished in the most satisfactory manner. The chief difference is in the cells of the outer or mucilaginous coat: these are smaller and more delicate than those of the husk of white mustard; they are perforated like them, however, but in addition they each seem to be made up of numerous angular very delicate and minute cells; these are very characteristic of the seeds of charlock (fig. 152).

Fig. 154.

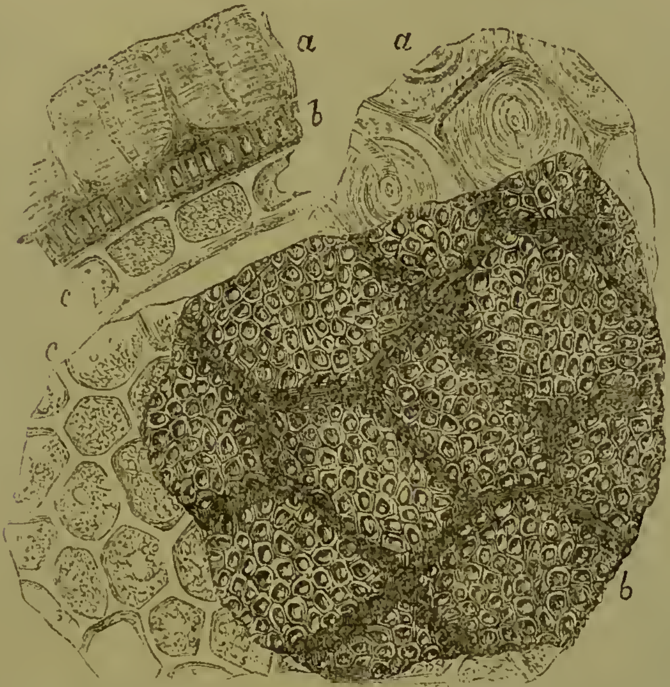


Husk of seed described as East Indian Rape, but which resembles a species of *Mustard*. Magnified 220 diameters.

Structure of rape seed.—The membranes forming the husk of rape seed are so distinct that no difficulty need be experienced in distinguishing this seed from those of any of the mustards. It is composed of two membranes, the outer resembling somewhat the second membrane of the husk of the mustards, but the cells are much larger, and in consequence their cavities do not appear black in general, but more or less light, the walls of the cells being thick and well defined; near the umbilicus of the seed the cells usually are disposed in a linear manner. The innermost membrane does not present any peculiarity (fig. 153).

In a sample of rape cake forwarded to us for examination, and suspected to be adulterated with mustard, we met with what appeared to be the husk of a species of mustard. It is represented in fig. 155.

Fig. 155.



Transverse and *Vertical Sections* of husk of a species of MUSTARD SEED met with in a sample of adulterated rape, and from the consumption of which some cattle are said to have died.

It approaches in structure most nearly to the husk of black mustard, but the cells of the first coat are perforated, and those of both the first and second coats are much larger; in the large size of the cells of the second coat it comes somewhat near to the husk of rape seed; but then in this we have never met with any outer coat of large colourless cells. The husk in question, therefore, belongs most probably to some foreign species of mustard.

Radish seed, on account of its price, is scarcely likely to be employed in the adulteration of mustard ; it is not necessary, therefore, to give a description of its structure.

THE DETECTION OF THE INORGANIC ADULTERATIONS.

For the discovery of the *inorganic adulterations* of mustard, recourse must be had to chemistry.

The process for the detection of *silicate of alumina* or *clay* is given at p. 143 ; of *gypsum* or *sulphate of lime*, at p. 144 ; and of *chrome yellow* or *chromate of lead* in the article on 'Coloured Sugar Confectionery.'

CHAPTER XXXI.

PEPPER AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any added vegetable or mineral substance or any extraneous mineral matter exceeding 1 per cent.

The natural family *Piperaceæ* includes four plants of great utility to mankind; two of these, *Piper nigrum*, or black pepper, and *Piper longum*, more recently named *Chavica Roxburghii*, or long pepper, are chiefly employed for dietetic and culinary purposes; whilst the others, *Piper cubeba*, now *Cubeba officinalis*, and *Artanthe elongata*, or the matico plant, are principally employed in medicine.

The plant which yields Cayenne, *Capsicum annuum*, often improperly termed Cayenne pepper, does not belong to the family of *Piperaceæ* at all, but to that of *Solanaceæ*.

The pepper of commerce is furnished by Piper nigrum, and it is to this species, therefore, that on the present occasion we shall have to direct attention.

The black pepper plant grows both in the East and West Indies, in Sumatra, Java, and other islands; it is a shrubby, climbing plant, which attains the height of from eight to twelve feet. The berries, or peppercorns, grow on terminal flowerstalks or spadices; they are at first green, but change subsequently to red and then to black. When any of the berries on a spadix have begun to turn red, the whole are gathered, dried in the sun, and the stalks separated by the hand. In drying, the succulent part of each berry becomes contracted and wrinkled, forming a hardened wrinkled cortex; the corrugations being much raised, and describing a kind of elevated network.

The following more detailed particulars concerning the growth of the pepper plant and the gathering of the berries are extracted from M'Culloch's 'Dictionary of Commerce':—

'It climbs to the height of twenty feet, but is said to bear best when restrained to the height of twelve feet. It begins to produce at about the third year, and is in perfection at the seventh; continues in this state for three or four years, and declines for about as many more, until it ceases to be worth keeping. The fruit grows abundantly from all its branches, in long, small clusters of from twenty to fifty grains;

when ripe it is of a bright red colour. After being gathered, it is spread on mats in the sun, when it loses its red colour, and becomes black and shrivelled as we see it. The grains are separated from the stalks by hand-rubbing. That which has been gathered at the proper period shrivels the least; but if plucked too soon, it will become broken and dusty in its removal from place to place. The vine produces two crops in the year, but the seasons are subject to great irregularities.'

Those berries are the best which are not too small nor too much corrugated; which are heavy, and sink readily in water.

The two varieties of pepper known as 'black' and 'white' pepper are both obtained from the same plant: black ground pepper is the entire berry reduced to powder, while the white consists of the same berry decorticated or deprived of its outer and black husk or covering.

We learn from Pereira that three kinds of *black pepper* are distinguished by wholesale dealers. These are:—

'*Malabar pepper.*—This is the most valuable; it is *brownish-black*, free from stalks, and nearly free from dust.'

'*Penang pepper.*—This is *brownish-black*, larger, smoother, free from stalks, but very dusty. It is sometimes used in England to manufacture white pepper.'

'*Sumatra pepper.*—This is the cheapest sort; it is *black*, mixed with stalks, and contains much dust. Under the name of Sumatra pepper, some dealers include the Penang or brownish-black sort, and the black Sumatra sort.'

Three kinds or varieties of *white pepper* have also been distinguished.

'*Tellicherry pepper*, which is of two kinds: large or fine Tellicherry pepper is larger and whiter than any other description of white pepper, and fetches a higher price; small or coriander-like pepper is shrivelled.'

'*Common white pepper* comes from Penang by Singapore; it is round, and not shrivelled; its value depends on its size and whiteness.'

'*English bleached, or white pepper.*—When the two preceding sorts are scarce, brown Penang pepper is bleached. The yellowest and largest grains are chosen for this purpose, for neither an expensive nor small sort would pay.'

COMPOSITION OF PEPPER.

The active properties of pepper depend upon the presence of *an acrid resin, a volatile oil*, and a crystallisable substance called *Piperine.*

The following is the composition of *black* and *white* pepper, according to Pelletier[1] and Lucä[2]:—

---

[1] 'Ann. de Chim. et de Phys.' xv. 344.

[2] Schwartze, 'Pharm. Tabella.'

Black Pepper (Pelletier).

Acrid soft resin.
Volatile oil.
Piperine.
Extractive.
Gum.
Bassorin.
Starch.
Malic acid.
Tartaric acid.
Potash, lime, magnesia, and salts.
Woody fibre.

White Pepper (Lucä).

Acrid resin	16·60
Volatile oil	1·61
Extractive, gum, and salts	12·50
Starch	18·50
Albumen	2·50
Woody fibre	29·00
Water and loss	19·29
	100·00

In Lucä's analysis the piperine is probably included in the resin.

The *resin* is very acrid, soluble in alcohol and ether, but not in volatile oil.

The *volatile oil* has the odour and taste of pepper. It boils at 167·5° C. and has a specific gravity of 0·864.

Piperine, $C_{17}H_{19}NO_3$, is a crystallisable substance, the crystals being monoclinic prisms with inclined bases; it fuses at 100° C. to a pale yellow oil, which solidifies on cooling to a yellow transparent resin. Specific gravity of fused piperine, 1·1931 at 18° C.; it is insoluble in cold water, and only slightly so in boiling water; it dissolves in alcohol, from which piperine is thrown down when water is added; ether and acetic acid also dissolve it, but the first is not so good a solvent as alcohol. It dissolves in volatile oils but not in alkalies. The alcoholic solution of the piperine has a very hot taste like that of pepper. With strong sulphuric acid it forms a blood-red liquid; nitric and hydrochloric acids turn it first greenish-yellow, then orange, and afterwards red.

The brown resin which is produced by the action of nitric acid on piperine, accompanied with the evolution of the odour of bitter almond oil, assumes a brilliant blood-red colour when treated with caustic potash, and when boiled with this it yields piperidine, which may be distilled over.

STRUCTURE OF PEPPER.

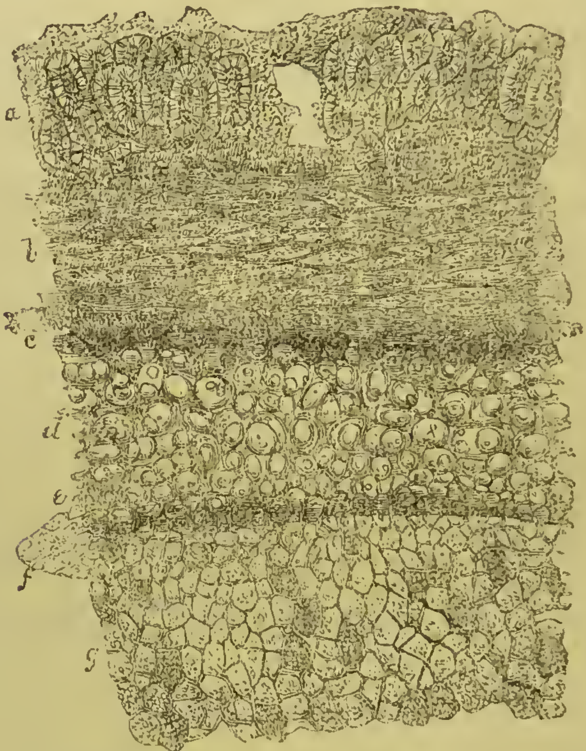
Structure of the berry.—The berry of the black pepper plant possesses a structure of considerable complication, and of much interest; and since without an accurate knowledge of its minute organisation we cannot hope to be in a position to detect the numerous adulterations to which this article is subject, it becomes necessary to describe somewhat minutely the tissues which enter into its formation.

In a section of the berry, two parts are to be distinguished—an outer and an inner: the first is black, or reddish-black; and the second more or less white, hard, and brittle, except in the centre of the seed, where it is frequently soft and pulverulent.

When a thin vertical section of the outer or cortical part of the berry is examined, by means of the microscope, it is seen to be composed of several distinct parts, each of which is constituted of one or more layers of cells. Such a section is represented in fig. 156.

The external part of the berry, marked *a* in the following figure, is constituted of cells of an elongated form, placed vertically. These cells are provided with a central cavity from which lines, probably minute canals or channels, radiate towards the circumference; when viewed sideways, they appear rather more than twice as long as broad; and when seen endways, they appear mostly oval in shape, and but little longer than broad. Cells of a somewhat similar character are described in the report on 'Sugar,' as entering into the formation of the epidermis of the sugar-cane.

Fig. 156.



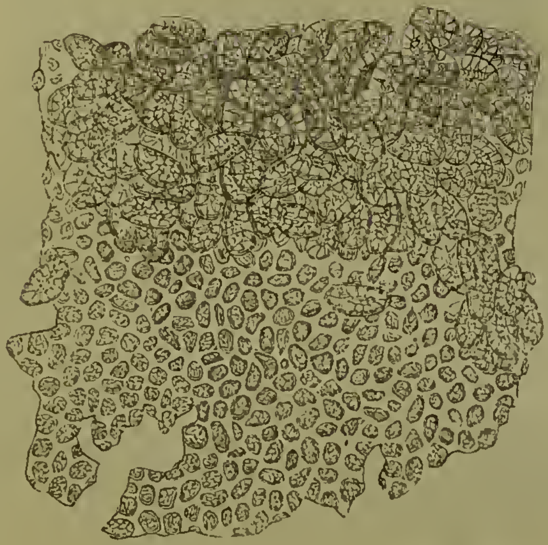
Section of a PEPPER BERRY, showing the several layers of cells of which the *cortical part* is constituted, and the junction of this at *f* with the central portion, *g*. Drawn with the Camera Lucida, and magnified 80 diameters.

The cells next in order, and upon which the previously described cells rest, are small, angular, and dark coloured: they, as well as the radiate cells, are shown in fig. 157.

The small angular cells, just noticed, do not appear to separate readily from the cells which occur immediately beneath them, and of which they are probably mere modifications; strictly speaking, therefore, they ought to be considered as forming part of the layer next to be described, and we have spoken of them separately only for convenience of reference and description.

The cells now to be described are two or three times larger than those previously noticed, and very numerous, forming about half the thickness of the cortex; they are all more or less coloured, and the colour deepens as the cells approach the next layer. The position of this second layer is pointed out at *b*, fig. 156. The third layer is very thin, and is composed of woody fibre, bundles of spiral vessels of small size, and formed of single threads (fig. 156, *c*).

Fig. 157.



A portion of the *cortex* of the PEPPER BERRY, viewed on the surface, showing the cells which form its first and second layers. Drawn with the Camera Lucida, and magnified 120 diameters.

The junction of the second with the third layer is pointed out by a dark line situated about the middle of the cortex (see fig. 156, *c*).

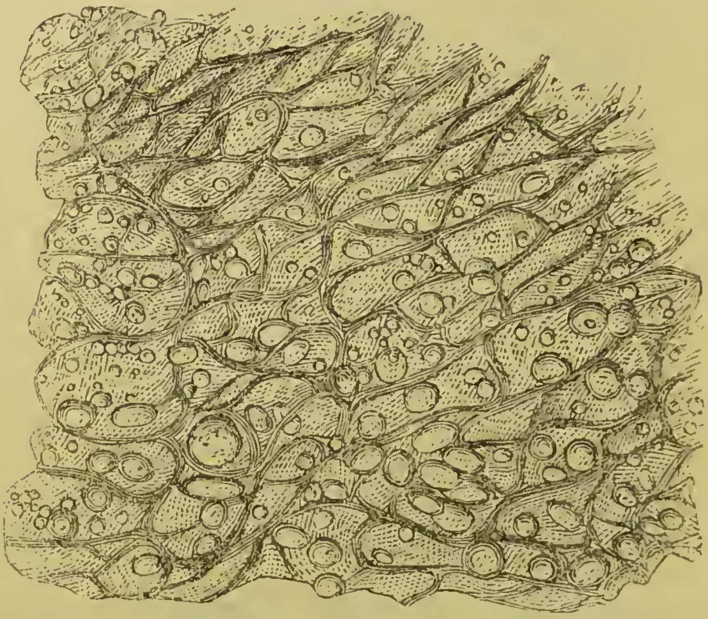
The fourth layer is composed of numerous large cells, and it constitutes the greater part of the remaining half of the cortex (fig. 156, *d*). As the cells approach the central part of the berry, they become much modified, two or three times smaller, and of a deep red colour (fig. 156, *e*); these cells might be described as forming a fifth and distinct layer.

The numerous cells which form the fourth layer contain a very great abundance of oil globules, and it is in it that the essential oil of the pepper berry is chiefly located (fig. 158).

The cells which form the fifth and last tissue which enters into the composition of the cortex of the pepper berry are divisible into two or three layers; the outer are coloured, and the inner invariably colourless; the colourless cells present a reticulated appearance, forming a transparent lamina which frequently separates, as a distinct tissue (fig. 156, *f*).

The *central part* of the berry or seed is constituted of cells of large size and angular shape; they are about twice as long as broad, and disposed in a radiate manner; in the outer part of the seed they are adherent, hard, and stonelike, while in the centre they are readily separable, and often form a powder resembling flour (fig. 156, *g*, and fig. 159).

Fig. 158.



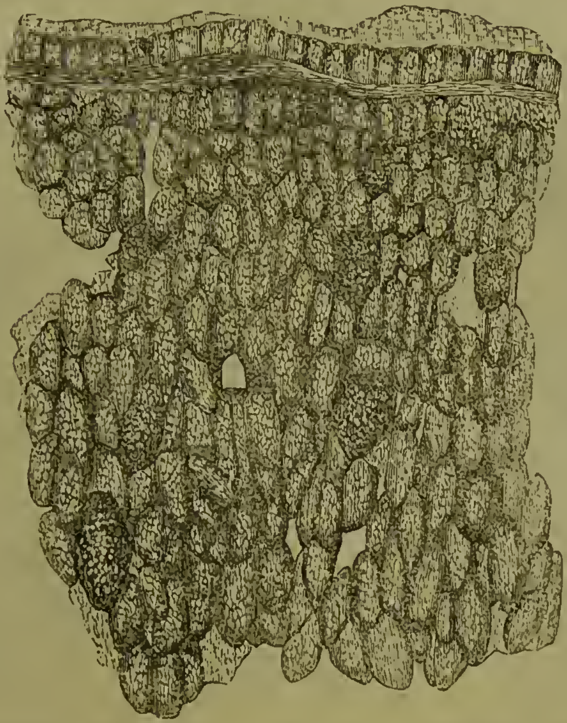
A portion of the *fourth lamina* of the cortex of PEPPER BERRY, showing the oil contained in the cavities of the cells. Drawn with the Camera Lucida, and magnified 120 diameters.

When the pepper berry is macerated in water for some hours, the cortical part apparently separates without difficulty from the seed proper; if, however, we examine the surface of this closely, we observe that it is of a reddish colour, and it becomes evident that a portion of the cortex is still adherent, this consisting of part of the fourth layer, containing much of the oil, and the fifth layer.

It now becomes apparent that the terms in common use, 'white pepper,' and 'decorticated pepper,' are not altogether correct, for the berry is not entirely denuded of the cortex, nor is its powder white, for if a little bit of it be diffused through water on a slip of glass, reddish particles immediately become visible: these are fragments of that portion of the cortex which remains firmly adherent to the seed itself.

When sections of the inner part of the pepper berry are immersed in water for a short time, they assume a yellowish or canary tint, and when examined with the microscope, the colour is seen to be confined to certain of the cells only, of which the sections are composed; these cells are rather larger than the ordinary cells; they are placed at tolerably regular distances from each other, and they reflect a deep yellow colour. In recent sections which have not been immersed in water, the cells, which afterwards become yellow, may be distinguished by a darker shading, and sometimes by a faint tint of colour. The deepening of colour is determined by the action of the salts contained

Fig. 159.

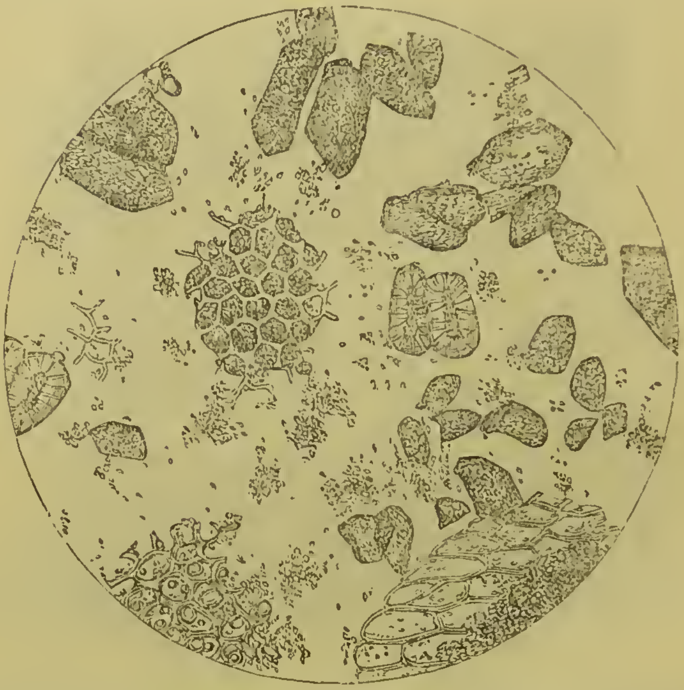


Section of the *central portion* of the PEPPER BERRY, showing the two kinds of cells of which it is composed, the colourless and coloured cells, and also its junction with the cortex. Drawn with the Camera Lucida, and magnified 120 diameters.

in water on the contents of these cells, which differ chemically from those of the ordinary cells.

It is probably in these coloured cells that the piperine is located. Alcohol and nitric acid deepen the tint very greatly, and on the application of concentrated sulphuric acid to dry sections of the pepper berry, they become of a reddish hue, the change of colour being limited, in the first instance, to the peculiar cells in question. These results of the use of sulphuric acid are such as ensue with piperine itself.

Fig. 160.



Ground and unadulterated Black Pepper. Drawn with the Camera Lucida, and magnified 120 diameters.

The structure of the central part of the pepper berry, and the position and character of the coloured cells, are shown in fig. 159.

Now, in ground black pepper, all the structures which we have described may be traced out in a broken and fragmentary condition (fig. 160), but in white pepper certain of these tissues only exist—viz., a part of the fourth layer of cells, which contains the oil, and the fifth cellular lamina.

Before the observer is in a position to detect the adulterations of pepper, it is necessary that he should well understand the appearances and structure of ground pepper, both black and white.

When black pepper is diffused through water, little particles of three different kinds, intermixed with a fine powdery substance, are visible; some of these are black, others reddish, and the last white; the black are fragments of the outer and the red those of the inner cortex, while the white are the pulverised seed itself. The white powder is formed of the cells of the seed, some united in twos and threes, but the majority either separated and entire or broken into pieces; these cells contain starch granules of extreme minuteness. The engraving (fig. 160) will serve to convey a good idea of the appearances presented under the microscope by ground and unadulterated black pepper.

In the black particles but little evidence of structure is in general to be seen, and where doubt is entertained of their nature, it is necessary that they should first be bleached with chlorine, torn into pieces with needles, and then examined with the microscope.

In genuine white pepper no black fragments ought to be seen, but numerous reddish-brown particles are always present, usually adherent to the white cells which form the central part of the berry.

These white cells, when separated from each other, whether entire or broken, being of angular form, very hard, and reflecting deep shadows, bear a strong resemblance to particles of sand, for which they would be very apt to be mistaken by persons unacquainted with the microscopic structure of the pepper berry.

The cavities of these cells are filled with starch granules of exceeding minuteness, and as in ground pepper many of the cells are broken into pieces, some of the granules become effused; these are so very small that they are generally in a state of molecular movement, and they resemble spherules of oil rather than starch granules. No other starch grains exist in the berry besides those just described.

So great is the quantity of starch contained in the seed or central part of the berry, that the cells when touched with a solution of iodine become deep blue; the yellow cells being affected in the same manner, but more tardily and to a less extent.

THE ADULTERATIONS OF PEPPER.

Pepper used formerly to be subject to very great and scandalous adulterations, and this although it is one of the few articles placed under the supervision of the Excise.

Results of the Examination of Samples.

Of *forty-three* samples of black and white pepper examined in 1851, we found *nearly one-half to be adulterated.*

The substances detected were *linseed meal, mustard husk, wheat flour, pea flour, sago, rice flour,* and *pepper-dust.* To this list must now be added *woody fibre,* recently met with by ourselves and also by the Excise.

Pepper dust, H.P.D. or P.D., consists either of the sweepings of the warehouses, or else of an article made up in imitation of ground pepper, and expressly used for the adulteration of that article.

Mr. George Phillips, of the Excise, gave the following evidence before the Committee on Adulteration, respecting the adulteration of pepper:—

'The number of samples examined in nearly twelve years was 1,116, of which 576 were found to be adulterated. We have found *rice, sago, potato starch, linseed meal, chilis, husks of red and white mustard, wheat bran* and *flour,* and ground *gypsum* or crystallised *sulphate of lime.* The stock material for adulterating pepper is the husks of red and white mustard seeds and linseed meal, warmed up with chilis.'

Of 100 lbs. of an article seized in 1852 at Chelmsford as pepper, 2 lbs. only consisted of pepper, the rest being husks of mustard, chilis, and rice. *Rape seed* has also been found in pepper. Mr. Gay, from whose evidence we have before quoted, states that white pepper is sometimes adulterated with *bone dust,* commonly called *ivory dust.* He also gave the following receipt for P.D.:—'It is manufactured from rape or linseed cake, mustard-husks, and Cayenne pepper.'

Many years since it was not uncommon to meet with *artificial pepper-corns*; instances of their occurrence are mentioned in Thomson's 'Annals of Chemistry,' and also by Accum, in the second edition of his celebrated work, 'Death in the Pot.'

Accum writes:—'I have examined large packages of both black and white pepper by order of the Excise, and have found them to contain about 16 per cent. of this artificial compound. This spurious pepper is made of oil-cake, the residue of the linseed from which the oil has been pressed, common clay, and a portion of Cayenne pepper, formed into a mass, and granulated by being first pressed through a sieve, and then rolled in a cask.'

The case of pepper used to afford a lamentable instance of the inefficiency of the Excise in checking adulteration.

The presence of Mineral Matter in Pepper.

A short time ago we received for analysis a sample of pepper, which had formed the subject of a prosecution under the late Adulteration Act. This was found to yield an ash amounting to 10·45 per cent., which on examination with the magnet, was ascertained to contain magnetic particles of oxide of iron and to furnish no less than 3·95 per cent. of silica. The results of the analysis of this sample of pepper led us to make other analyses of pepper in order that we might be in the position to form a correct opinion as to the significance of the details above recorded.

Various samples of pepper, including the whole berries of white and black ground peppers, were subjected to examination, with the results shown in the following tables:—

Description of Pepper.	Total Ash.	Sand.	Ash, whether magnetic or not.
1 Whole white	1·73	0·70	Non-magnetic.
2 ,,	0·90	0·17	,,
3 ,,	1·03	0·20	,,
4 ,,	1·14	0·26	,,
5 ,,	0·94	0·13	,,
6 ,,	1·55	0·24	,,
7 ,,	1·56	0·16	,,
8 Whole black	4·03	0·23	Slightly magnetic.
9 ,,	4·33	0·29	,,
10 ,,	3·90	0·17	,,
11 ,,	4·61	0·12	,,
12 ,,	4·01	0·11	,,
13 ,,	3·67	0·18	,,
14 Ground white	2·03	0·37	,,
15 ,,	1·13	0·20	,,
16 ,,	0·50	0·13	,,
17 ,,	2·13	0·50	,,
18 Ground black	9·95	4·85	Strongly magnetic.
19 ,,	11·50	4·95	,,
20 ,,	9·55	3·25	Slightly magnetic.
21 ,,	9·80	5·15	,,
22 ,,	5·95	1·95	,,
23 ,,	7·55	3·00	,,
24 ,,	7·63	2·07	,,
25 ,,	9·76	3·83	,,
26 ,,	6·64	1·46	,,
27 ,,	9·20	2·57	,,
28 ,,	6·46	2·17	Strongly magnetic.
29 ,,	3·50	1·13	Slightly magnetic.
30 ,,	9·37	3·91	,,
31 ,,	6·86	2·41	,,
32 ,,	7·05	3·21	,,
33 ,,	9·93	4·30	Decidedly magnetic.

The foregoing results may be summarised as follows:—

Description of Pepper.	Average Ash.	From	To	Average of Sand.	From	To
White whole pepper	1·26	0·90	1·73	0·27	0·13	0·70
Black ,, .	4·26	3·67	4·61	0·18	0·11	0·27
White ground pepper	1·45	0·50	2·13	0·30	0·13	0·50
Black pepper . .	7·92	3·50	11·50	3·13	1·13	4·95

The general conclusion deducible from the foregoing analyses is, that a great proportion of the black peppers sold in shops contain a considerable admixture of earthy matter, composed to a large extent of silica. This quantity is far in excess, as will be seen from the analyses, of anything which the whole black berries afford.

We have now to enquire—In what manner is the presence of this earthy matter, and of the magnetic particles, to be explained? Is it accidental or intentional?

The results of the analysis of some of the whole black peppers tend to show that an appreciable amount of silica may be present in ground black pepper, derived from the cortex, and hence it may be inferred that if the original whole pepper be of a dusty kind, or if it be taken from the bottom of the bag or sack, it is possible to conceive that the quantities we have detected may thus be accounted for. Still, this large amount of foreign matter has no right to be present, and it would be a very easy and simple thing to free the berries before they are ground from nearly the whole of this dust. The few magnetic particles discovered would appear to be derived from the surrounding soil.

The presence of this dirt is due simply to want of care and cleanliness in the drying of the berries, and its presence should be strongly condemned. We would say that not more than 1 per cent. of extraneous mineral matter should be allowed to be present in pepper, and that any quantity beyond this should be regarded as an adulteration. However dusty the pepper may be when bought by our own dealers, they might, where they are so disposed, very readily free it from nearly every particle of extraneous matter before it is ground.

THE DETECTION OF THE ADULTERATIONS OF PEPPER.

The whole of the adulterations of pepper mentioned, except that with the husk of pepper, are only to be detected in a certain and satisfactory manner by means of the microscope.

The characters of the starch granules of wheat, rice, and potato, have already been described and figured; those of wheat at p. 289, those of rice at p. 308, of potato flour at p. 371, and of sago at p. 376.

The structure of *mustard* and *rape seed*, and of *Cayenne*, will be found described and figured under the heads of 'Mustard' and 'Cayenne;' the method of detecting *sulphate of lime* is given at p. 144.

It then only remains for us to describe the structure and appearances of *linseed meal* and of *pea flour*.

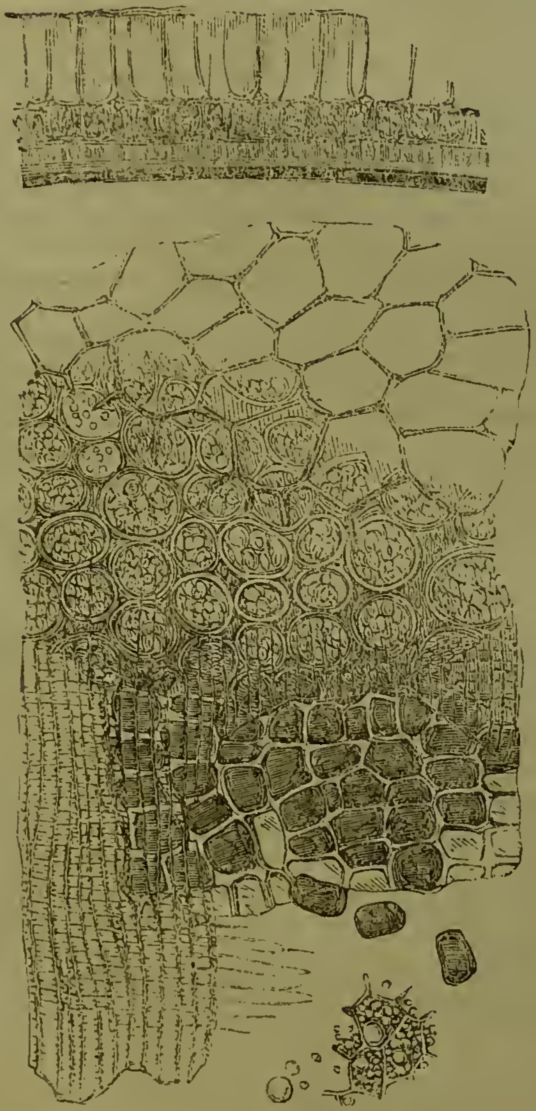
Structure of Linseed Meal.

Linseed possesses a very beautiful structure: four coats or tunics enter into the composition of the covering of the seed, and require description.

The *outer* coat gives the polish to the seed, and is composed of a single layer of large and colourless cells, of an hexagonal form.

It is in the cells which form this tunic that the mucilage which linseed yields so abundantly, on infusion, is contained.

Fig. 161.



Structure of LINSEED. Magnified 220 diameters.

The *second* coat consists of a single layer of cells enclosing granular matter; they are of a rounded form, and have thick walls.

The *third* membrane is composed of narrow elongated cells, or rather fibres, some being longitudinal and others transverse; these give it a striated and very characteristic appearance; being firm and strong, it forms the protecting tunic of the *seed.*

The *fourth* membrane is made up of angular cells, many of which are more or less square, enclosing masses of colouring matter, probably of a resinous character, and which readily fall out of the cells, as represented in the figure.

The *substance of the seed* consists of cells, in the cavities or meshes formed by which the oil and starch granules are enclosed (fig. 161).

The *oil* is contained principally in the outer or more superficial cells, in the form of brilliant and pearl-like minute drops or spherules.

The *starch granules* are most abundant in the interior of the grain; they are angular, minute, and two or three times larger than those of the peppercorn.

The whole of the structures above described may be satisfactorily detected, by a little patient investigation, in the linseed reduced to powder or meal. The parts, however, most frequently and clearly seen, are fragments of the fibrous coat, and little masses of the seed, from the edges of which, portions of the cellulose forming the transparent cells project, in a radiate and very characteristic manner.

Structure of pea flour.—Pea flour resembles very closely bean flour, already described and figured under the article 'Bread.' The chief difference consists in the size of the starch corpuscles, which are much smaller in pea than in bean flour.

On the detection of pepper husks.—The presence of an undue quantity of pepper husks in black pepper may be suspected by the appearance of the article, its dark colour, and the quantity of husk visible to the naked eye.

It is not often that such an analysis is necessary.

On the detection of factitious pepper berries.—The suspected pepper should be soaked for some time in water, when, should it contain artificial peppercorns, these will become disintegrated and fall to pieces. Their composition is to be ascertained partly by chemical analysis and partly by microscopical examination. Pepper is now so cheap, however, that it is not likely that any instance of this adulteration will ever again be met with.

The processes for the detection of *sulphate of lime* and *bone dust* have already been described elsewhere.

CHAPTER XXXII.

CAYENNE AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any added vegetable or mineral substances, including those used for colouring.

Cayenne Pepper consists of the pods or seed vessels, ground and reduced to powder, of different species of *Capsicum*, but principally of *C. annuum*, *C. baccatum*, and *C. frutescens*; the latter species, being stronger and better flavoured, yields the best description of Cayenne pepper.

The genus Capsicum belongs to the *Solanaceæ* or Nightshade family, which also includes the potato plant.

Capsicum annuum is a native of America, but is cultivated in the West and East Indies, and to some extent in greenhouses in England and other European countries.

It is an annual herbaceous plant, and, according to M'Culloch, 'one of the hardiest and most productive plants found in tropical climates, growing luxuriantly in almost all dry soils, however indifferent.' In this country it flowers in July, and ripens its pods in October; when immature, the berries are green, and only gradually become red as they grow ripe; they are used both in the green and red states, and in the undried and dried conditions; in the recent state they are employed for pickling; when dried they are used in medicine; and, reduced to powder, they constitute Cayenne pepper.

The dried berries ordinarily sold as *chillies* are of this species; in this condition they are more or less shrivelled, oblong, broad at the distal extremity, the calyx and stalk being usually adherent to the broad end. They vary very much in size and form; the largest are two or three inches long, and at the base are an inch or more wide; they are distinguished, according to their size and shape, into long-podded, short-podded, and heart-shaped.

The pods of this capsicum are hot and pungent, but they have *no aroma.*

The pods of *Capsicum frutescens* constitute what is known as *Guinea* or *Bird pepper*, and when ground they furnish the best description of Cayenne pepper. They are small, scarcely an inch in length, a line or two broad, and of a deep orange-red colour. Each berry encloses usually about a dozen flattened, reniform seeds.

The pods are hotter and more fiery than those of *C. annuum*; they are likewise to some extent *aromatic.*

The other species of Capsicum have been denominated, from the form of the fruit, *Cherry chilly* or *Cherry pepper—Capsicum cerasiforme,* and *Bell pepper,* or *Capsicum grossum.*

Composition of Cayenne.

The composition of capsicum berries is shown in the following analyses made in the years 1816 and 1817:—

Bucholz's analysis.

(1816.)

Acrid soft resin (*capsicin*)	4·0
Wax	7·6
Bitter aromatic extractive	8·6
Extractive with some gum	21·0
Gum	9·2
Albuminous matter	3·2
Woody fibre	28·0
Water	12·0
Loss	6·4
Fruit of *Capsicum annuum,* without seeds	100·0

Braconnot's analysis.

(1817.)

Acrid oil	1·9
Wax with red colouring matter	0·9
Brownish starchy matter	9·0
Peculiar gum	6·0
Animalised matter	5·0
Woody fibre	67·8
Salts: citrate of potash 6·0 Phosphate of potash, and Chloride of potassium 3·4	9·4
Fruit of *Capsicum annuum*	100·0

Of *capsicin,* the active principle of Cayenne, Pereira gives the following account:—

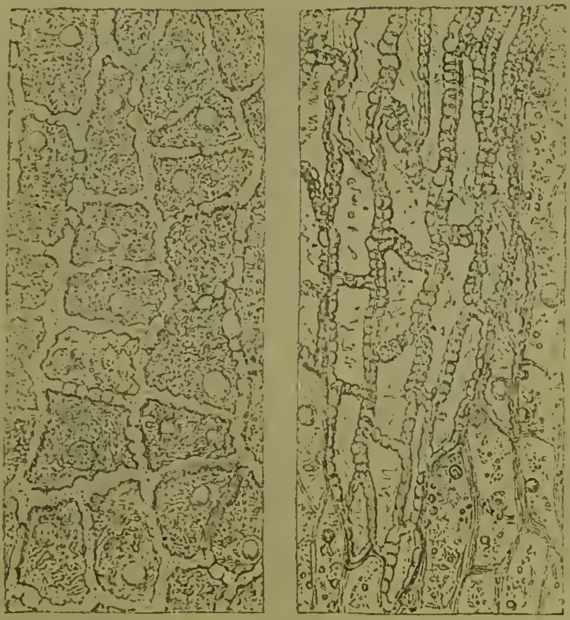
'Obtained by digesting the alcoholic extract in ether, and evaporating the ethereal solution. It is a thick liquid, of a yellowish-red or reddish-brown colour, which becomes very fluid when heated, and at a higher temperature is dissipated in fumes. Half a grain of it volatilised in a large room causes all who inspire the air of the room to cough and sneeze. By exposure to air and light it solidifies; it is decolorised by chlorine; it is slightly soluble in water and in vinegar, but very much so in alcohol, ether, oil of turpentine, and the caustic alkalies; with baryta it forms a solid acrid combination.'

Structure of the Capsicum Berry or Fruit.

Each capsicum berry is made up of three parts—an outer skin or epidermis, parenchyma, and seeds.

The *epidermis* consists of flattened cells, tortuous and angular in form. Viewed on the outer or upper surface, the borders of the cells are seen to be well defined; they are often four-sided; the walls are thick, beaded here and there, the beading of one cell corresponding to that of the contiguous cells; lastly, the lines of junction of the cells are sometimes faintly indicated.

Fig. 162.



EPIDERMIS of CAPSICUM, outer and inner surfaces. Magnified 200 diameters.

Viewed on the inner surface the cells appear less angular, but more tortuous, the walls broader, and much more beaded (fig. 162).

When fragments of the epidermis are seen immersed in water, numerous oil globules of a deep and beautiful orange-red colour are visible; some of these are imbedded in the cavities of the cells, but the majority float freely in the surrounding water (fig. 162).

In figures 163 and 164 the general appearance presented by the epidermis on a more superficial examination is exhibited, the minute details being omitted.

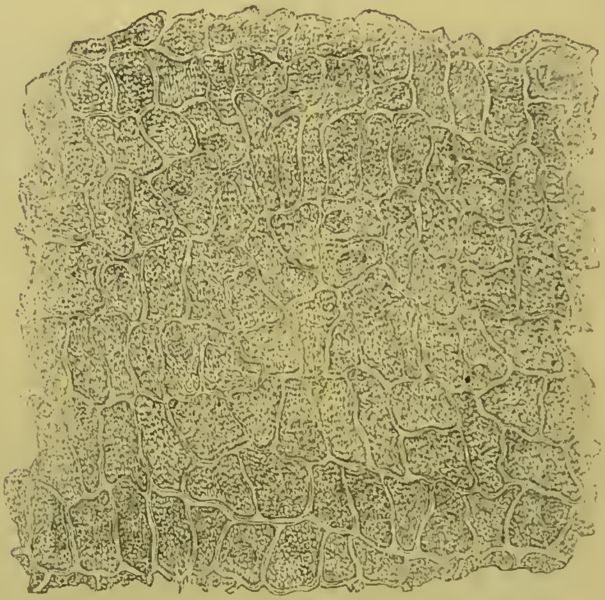
The *parenchyma*, which unites the seeds with each other, and the whole with the epidermis and peduncle, is likewise composed of cells; they are of a rounded or oval form, the parietes are thin, and their cavities usually contain a very large quantity of oil, in the form of innumerable droplets, many of considerable size, and which impart to this object, viewed under the microscope, a very beautiful appearance (fig. 165).

Fig. 166 represents a section of the cortical portion of the pod.

In the *seed,* two parts—the covering of the seed and the seed itself—require to be described.

The covering of the seed possesses a very peculiar structure, which it is difficult fully to understand, and therefore not easy to describe accurately. It is of a bright yellow colour, and of considerable thickness. Viewed under the microscope, its outer surface presents a cellular texture, the margins of what appear to be the cells being thick and tortuous, and the cavities dark and depressed, as though they were rather apertures than the hollow interiors of the cells.

Fig. 163.

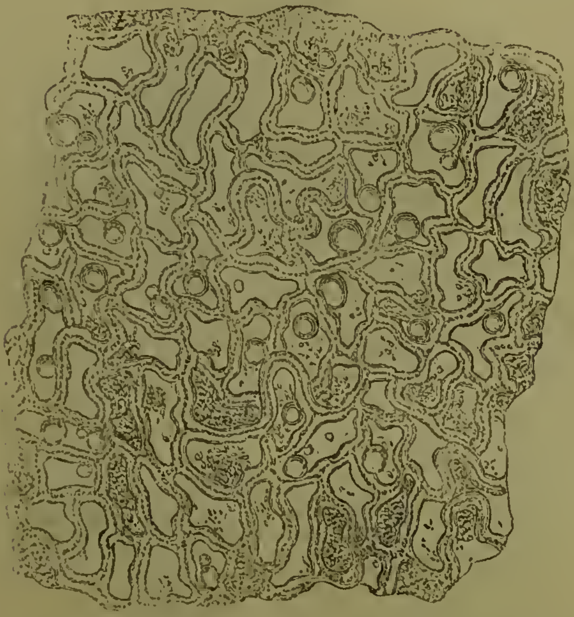


A fragment of the *epidermis* of the Capsicum Berry, viewed on its outer surface.

Vertical sections of this covering present a very singular appearance. In this view it appears as though composed of a number of tooth-like processes, having a somewhat radiate disposition, with intervals between each process, the points or summits of the teeth ending in very minute hook-like spines, the points of these being lost in a thin membrane forming the external covering of the seed. It appears that these tooth-like processes really consist of the thickened walls of contiguous cells (fig. 167); that this is really so is evident from an examination of the upper of the two sketches on the left of the figure; these cells are best developed at the extremity of the seed.

The seed proper consists of minute angular cells, having thick and colourless parietes; their cavities are filled with molecules and globules of oil of a yellowish or reddish-yellow colour, but do not contain starch.

Fig. 164.



A fragment of the *epidermis* of the CAPSICUM BERRY, viewed on its inner surface.

THE ADULTERATIONS OF CAYENNE.

Cayenne is subjected to even more extensive adulteration than ordinary pepper.

Results of the Examination of Samples.

Of *twenty-eight* samples of Cayenne submitted to microscopical and chemical examination, no less than *twenty-four were adulterated, and four only were genuine.*

Twenty-two contained *mineral colouring matters.*

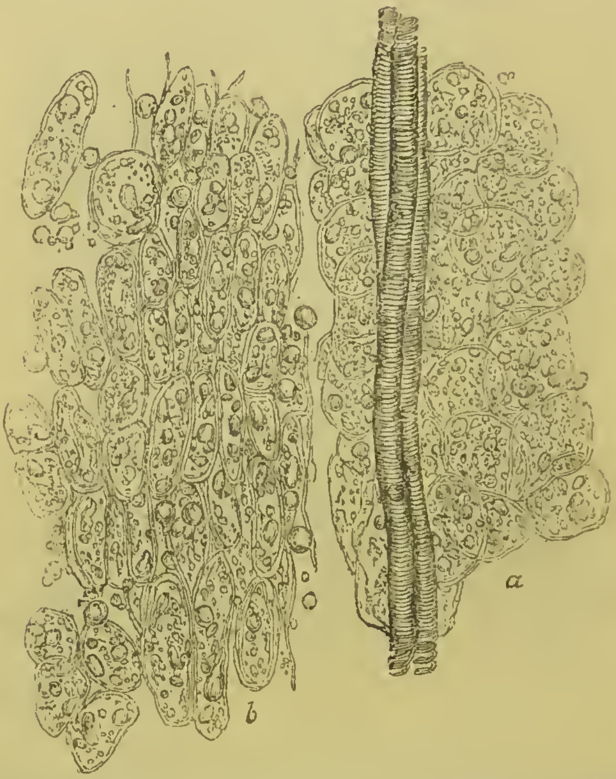
In *thirteen* cases this consisted of *red lead*, which was present in some of the samples in very considerable quantities, while in the remaining seven samples it was some red ferruginous earth, *Venetian red* or *red ochre.*

Vermilion, or *sulphuret of mercury,* was present in one of the Cayennes.

Six of the Cayennes consisted of a mixture of *ground rice, turmeric,* and *Cayenne,* coloured with either *red lead, Venetian red,* or *ochre.*

Six of the Cayennes contained large quantities of *salt,* sometimes alone, but mostly combined with *rice* and the *red earths* or *red lead.*

Fig. 165.



a, parenchyma of CAPSICUM BERRY situated immediately beneath the epidermis; the cells in this situation are of a more rounded form, and are traversed by spiral vessels and woody fibre. *b,* the *parenchyma* surrounding the seeds.

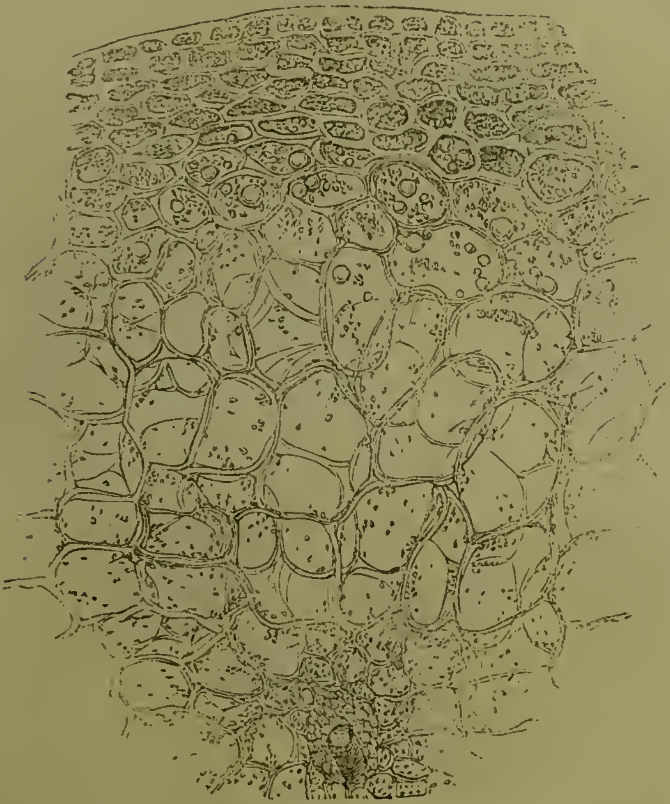
One of the samples was adulterated with a large quantity of the *husk of white mustard seed.*

Lastly, *two* were adulterated with *rice,* and were coloured in addition, the one with *red lead,* and the other with a *red ferruginous earth.*

The object of the use of red lead and other red colouring matters is twofold: first, to conceal other adulterations, and, second, to preserve the colour of the Cayenne, as, when exposed to the light for any time, it usually loses part of the bright-red colour which it at first possesses, and therefore it becomes deteriorated in the eyes of the purchaser. The red lead, &c., added does not, of course, *preserve* the colour of the Cayenne, but simply supplies the place of that which it loses in consequence of exposure.

Salt is employed for the same purpose. This substance has a remarkable effect in bringing out the colour of the Cayenne. It is, however, also used to increase its weight.

Fig. 166.



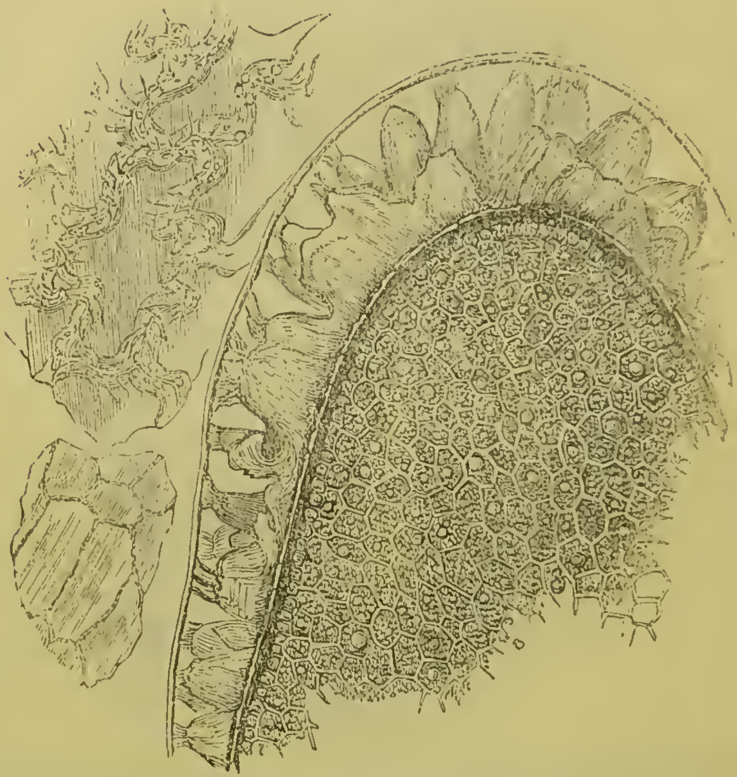
Transverse Section of CAPSICUM BERRY. Magnified 100 diameters.

The adulteration of Cayenne with such substances as red lead and mercury is, doubtless, highly prejudicial to health; it has been stated that colic and paralysis have both been produced by the use of Cayenne containing red lead.

The salts of lead and mercury are characterised by the circumstance that they are apt to accumulate in the system, and so to produce symptoms of a very serious nature. Thus, no matter how small the quantity of mercury or lead introduced each day, the system in the end is slowly and insidiously brought under the influence of these poisons, and thus becomes seriously affected. The quantity of red lead introduced into the system in adulterated Cayenne is, however, *by no means inconsiderable.*

A case of lead poisoning arising from the consumption of Cayenne adulterated with red lead is referred to in the evidence of Mr. Postgate before the Parliamentary Committee on Adulteration in 1855; the case was received into University College Hospital. The man was in the habit of consuming large quantities of Cayenne, which, on being tested, was found to contain lead.

Fig. 167.



Vertical Section of the *Seed* of CAPSICUM. Magnified 100 diameters.

The article known as *soluble Cayenne*, Mr. Scanlan stated before the same Parliamentary Committee, to have the following composition:—‘It contains both copper and vermilion; the copper is accidentally introduced into it from the mode of preparation—it is taken from a copper still. They make a sort of tincture of the Cayenne pepper; and then filter and pour it upon a quantity of salt in a copper still—it there takes up a little copper; and then this salt is dried and mixed with vermilion and rose-pink.' The proportion of vermilion added is about six drachms to three pounds of salt.

The Detection of the Adulterations of Cayenne.

The adulterations of Cayenne with *rice flour, turmeric,* and *mustard husk,* are determined by means of the microscope; the structure of these articles has already been described and their microscopical characters represented.

For the detection of the other adulterations of Cayenne, recourse must be had to chemistry. The fact of the presence of red earths may indeed be ascertained by means of the microscope, by viewing under that instrument a portion of the Cayenne, when the red earthy particles may be plainly discerned. To determine their composition, however, chemistry must be appealed to.

The method for detecting the presence of the red ferruginous earths, and for their quantitative determination, will be found described at pp. 111 and 190, and that for salt under the head of 'Water,' pp. 83 and 86. We have, then, now to describe more particularly the processes to be followed for the detection of lead and mercury.

On the detection of lead.—The presence of lead in Cayenne may be determined by simply shaking up half a drachm or so of the Cayenne in water, and adding a few drops of sulphide of ammonium; if lead be present, the liquid will become more or less dark or black, according to the quantity of the metal.

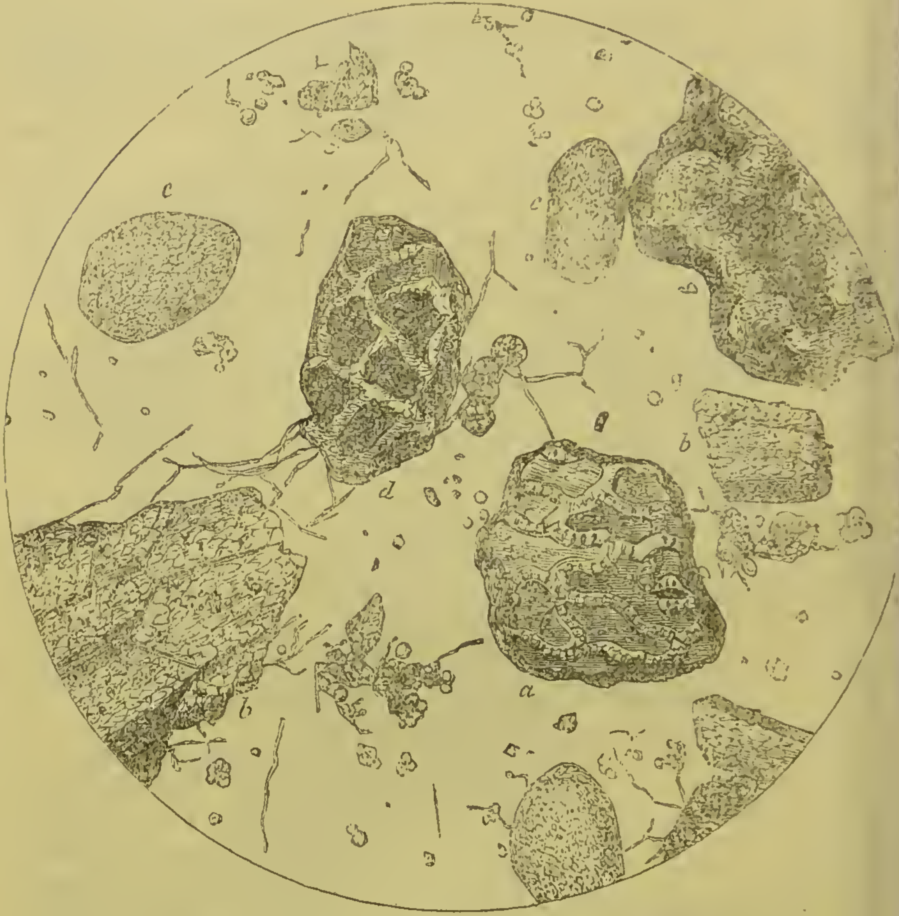
But it should be remembered that iron gives a greenish-black precipitate with the above-named reagent; and therefore it is not safe to trust to the appearance presented on the addition of solution of sulphide of ammonium to water containing Cayenne.

It is proper, therefore, in all cases to proceed as follows:—Incinerate 10 grammes of Cayenne previously dried on a water-bath in a porcelain basin; treat the ash with about 5 cc. of strong nitric acid; heat nearly to dryness, so that part of the acid may become dissipated; dilute with distilled water, filter, and pass sulphuretted hydrogen through the solution. The precipitate is collected on a filter, washed with water containing some sulphuretted hydrogen in solution, and then boiled with a little strong nitric acid. To the liquid a few drops of sulphuric acid are added, and it is then evaporated to dryness on the water-bath. The residue is exhausted with water, and the precipitate, consisting of sulphate, of lead is collected on a filter, washed with a very dilute solution of sulphuric acid, incinerated in a porcelain crucible and weighed.

The solution of the ash of Cayenne in nitric acid may be tested qualitatively for lead by rendering it alkaline by means of ammonia, adding then acetic acid in excess and testing with a drop of a solution of neutral chromate of potash. A bright yellow precipitate of chromate of lead will be thrown down if lead be present.

On the detection of bisulphuret of mercury.—As *mercury* sublimes at a red heat, we cannot proceed in the analysis by incineration; the solvent must be added to the Cayenne direct—this being aqua regia, a mixture of nitric and hydrochloric acids, in the proportions of one part of the former to two of the latter acid.

Fig. 168.



CAYENNE, adulterated with, *a a*, *red lead*; *b b*, ground *rice*; and *c c*, *turmeric*. *d d*, husk and seed of *cayenne* much infested with the *thallus* and *sporules* of a *fungus*, to the attacks of which damaged cayenne is very subject.

About 5 cc. of the acid should be added to 3 grammes of Cayenne and boiled with it for an hour or so; a small quantity of distilled water is then to be added; the mixture filtered and the filtrate evaporated nearly to dryness; a little water must then again be added, and the solution tested.

The tests employed are liquor potassæ and iodide of potassium. The former gives a yellow precipitate, and the latter either a yellow or more commonly a beautiful scarlet-coloured precipitate of biniodide of mercury. The solution of iodide of potassium should be added in very minute quantity, as the iodide or biniodide is readily and almost instantly dissolved in an excess of this reagent; and it should be known that very often, when the colour of the precipitate is yellow rather than red, after standing an hour or two it will frequently change to the characteristic scarlet hue.

To determine the quantity of the mercury in Cayenne, the solution in nitric acid is precipitated by means of sulphuretted hydrogen; the precipitate is exhausted with a solution of sulphite of soda, to remove any free sulphur which may have been thrown down, collected on a weighed filter, dried and weighed.

CHAPTER XXXIII.

SPICES AND THEIR ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any added vegetable or mineral substance not acknowledged in the names under which they are sold, including the admixture of cassia with cinnamon or its substitution for the latter spice.

We now come to the consideration of the important subject of Spices and their Adulterations.

The spices, of the adulteration of which we are about to treat, are *Ginger*, *Cinnamon*, *Cassia*, *Nutmegs*, *Mace*, *Cloves*, and *Allspice* or *Pimento*.

When it is remembered that many spices are sold in the state of powder, most of them bearing a high price, and that they are nearly all subject to a duty, which in some cases is considerable, it might be supposed that they would be particularly subject to adulteration.

Notwithstanding these facts, little attention has been bestowed upon this subject by writers on the sophistication of food, or even by the Excise authorities, whose duty it is to protect the revenue from all frauds resulting from the adulteration of duty-paying articles.

GINGER AND ITS ADULTERATIONS.

The ginger plant, *Zinziber officinale*, belongs to the very useful natural order, *Zinziberaceæ*, from which turmeric, East India arrowroot, and some other productions, are obtained.

Ginger grows and is cultivated in the tropical regions of Asia, America, and Sierra Leone.

The stem reaches generally three or four feet in height, and is renewed yearly; while the root, which is the part known as ginger, botanically termed a *rhizome*, is biennial.

The roots, or rhizomes, are dug up when about a year old; in Jamaica this occurs in January or February, and after the stems are withered. They are well washed, freed from dirt, and in some cases, especially with the better kinds, the epidermis or outer coat is stripped off; and hence the division of ginger into white (scraped or uncoated), and into black (unscraped or coated).

In estimating the quality of ginger, a variety of particulars have to be taken into consideration—as whether the rhizomes are coated or uncoated, their form, colour, and consistence.

The rhizomes of ginger of *good quality* have no epidermis, are plump, of a whitish or faint straw-colour, soft and mealy in texture, with a short fracture, exhibiting a reddish, resinous zone round the circumference; the taste should be hot, biting, but aromatic.

The rhizomes of ginger of *inferior quality* are frequently coated with the epidermis, are less full and plump, often contracted and shrivelled; of darker colour, being of a brownish-yellow; of harder texture, termed *flinty*; and more fibrous; while the taste is inferior, and less aromatic.

Composition of Ginger.

Ginger was analysed by Bucholz in 1817, and by Morin in 1823.

Bucholz's analysis.	
Pale yellow volatile oil . . .	1·56
Aromatic, acrid, soft resin .	3·60
Extractive soluble in alcohol .	0·65
Acidulous and acrid extractive insoluble in alcohol . .	10·50
Gum	12·05
Starch, analogous to bassorin .	19·75
Apotheme, extracted by potash (ulmin?)	26·00
Bassorin	8·30
Woody fibre	8·00
Water	11·90
	102·31

Morin's analysis.

Volatile oil.
Acrid soft resin.
Resin insoluble in ether and oil.
Gum.
Starch.
Woody fibre.
Vegeto-animal matter.
Osmazoma.
Acetic acid, acetate of potash, sulphur.
The ashes contained carbonate and sulphate of potash, chloride of potassium, phosphate of lime, alumina, silver, and oxides of iron and manganese.

The *volatile oil* is pale yellow, very fluid, lighter than water; odour resembling that of ginger, taste at first mild, afterwards hot and acrid.

Soft resin, obtained by digesting the alcoholic extract of ginger, first in water, then in ether; it possesses an aromatic odour, and a burning aromatic taste. It is readily soluble in alcohol, ether, and turpentine.

Structure of Ginger.

Examined with the microscope, the rhizome of ginger is found to present a well-marked and characteristic structure.

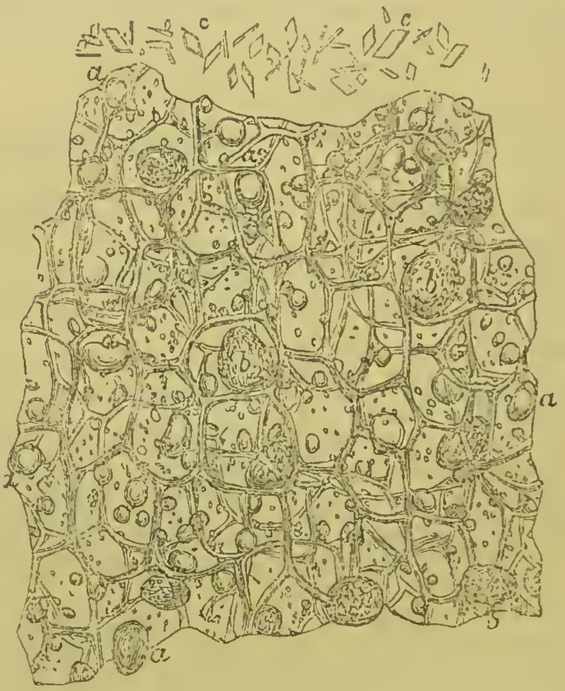
The outer coat or epidermis consists of several layers of large, angular, transparent cells of a brownish colour, adhering firmly together, forming a distinct membrane, and, when macerated in water, becoming soft and somewhat gelatinous (fig. 169).

Lying upon the under surface of this membrane, and scattered irregularly over it, are generally to be detected oil globules of various sizes, and of a deep yellow colour, as well as a few cells, identical in structure and tint with those of turmeric.

In the substance of the rhizome itself several structures have to be described.

It consists principally of cells having delicate transparent walls minutely punctuated, and adhering together so as to form a connected tissue. These cells contain in their cavities starch corpuscles, which are very abundant, and many of which, as the cell walls are easily broken, are seen in most sections to have become effused.

Fig. 169.



A portion of the *epidermis* of the rhizome of GINGER, showing the cells of which it is composed, as well as the oil globules, *a a*; also the turmeric-like cells, *b b*; and *c c*, crystals very commonly noticed in great numbers lying beneath the epidermis.

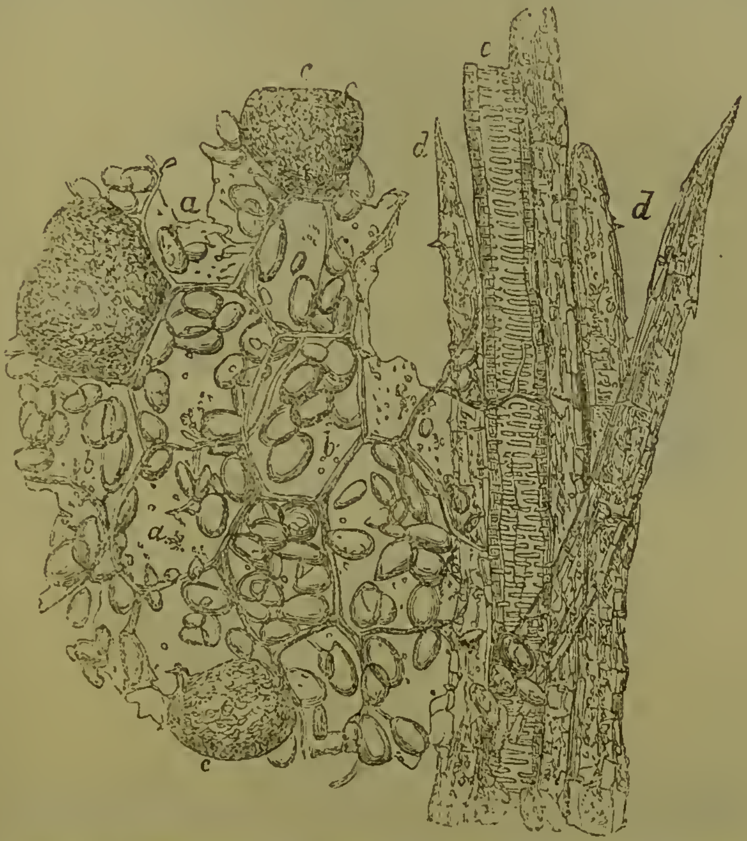
Lying here and there in the midst of the above-described cells, are other cells of nearly similar size and form, but of a bright yellow colour; these are in no respect distinguishable from the coloured cells of turmeric.

It is to the presence of these cells that ginger owes its colour, which varies with the number of such cells contained in it.

Traversing the rhizome in a longitudinal direction are bundles of woody fibre, sometimes enclosing, usually one, but occasionally two or even more dotted ducts or vessels.

The starch corpuscles resemble in some respects those of East India arrowroot, *Curcuma angustifolia*, but are yet characterised by several distinct features.

Fig. 170.



This engraving represents the several tissues observed entering into the formation of the *ginger rhizome*, deprived of its epidermis. *a a*, cells containing the starch corpuscles ; *b b*, starch granules ; *c c*, turmeric-like cells ; *d d*, woody fibre ; *e*, dotted duct.

Although, like those of *C. angustifolia*, they are usually elongated nd flattened, they yet differ from the starch granules of that plant in eing somewhat smaller, less elongated, and in the greater obscurity of the hilum and curved lamellæ.

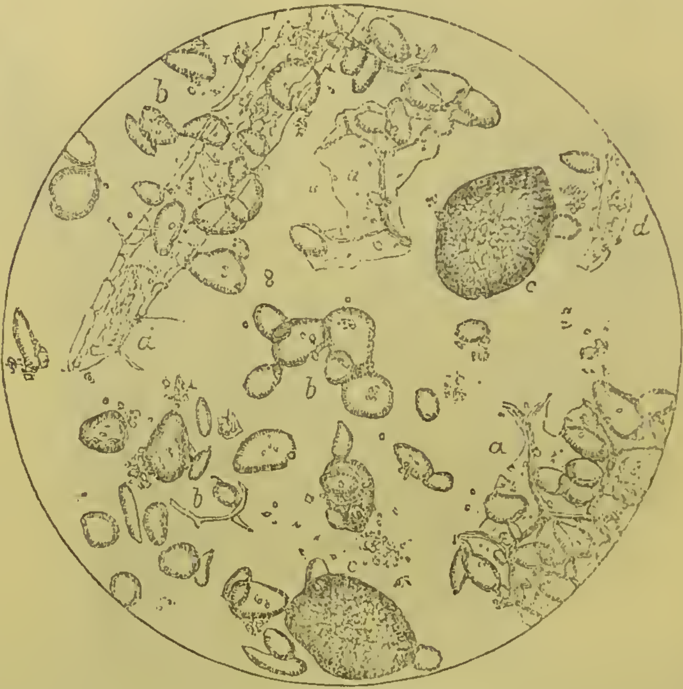
The structures above described are shown in the preceding rawing (fig. 170).

In ground ginger the above structures are separated from their proper connection, and occur variously intermixed, and more or less broken and comminuted (see fig. 171).

THE ADULTERATIONS OF GINGER.

In order to improve the colour of ginger, and, according to some, to protect it from the attacks of insects, it is frequently rubbed over with lime; in other cases it is washed in chalk and water, when it is called *whitewashed ginger*; lastly, the surface of ginger is occasionally bleached by means of a solution of chloride of lime, and sometimes even by exposing it to the fumes of burning sulphur, and is thus made to present a white and floury appearance. By these processes an inferior ginger is often made to assume the appearance of the better descriptions.

Fig. 171.



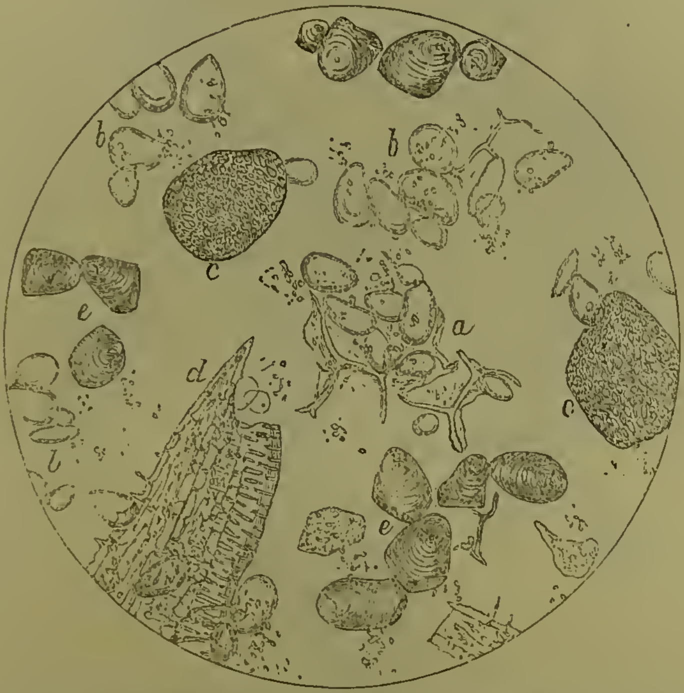
Genuine ground Ginger: *a a*, cells which contain the starch corpuscles; *b b*, loose starch granules; *c c*, turmeric-like cells; *d d*, woody fibre.

But ginger is frequently adulterated. Out of *twenty-one* samples of ginger submitted to examination, no less than *fifteen*, being more than two-thirds of the whole, were found to be *adulterated*.

The substances detected were various in character, including *sago meal, tapioca, potato flour, wheat flour, ground rice, Cayenne pepper, mustard husks*, and *turmeric powder*—these occurring in various quantities, but in the majority of cases constituting the principal part of the article.

The Cayenne pepper and mustard husks are no doubt added with the view of concealing the other adulterations, and of giving apparent strength to the ginger.

Fig. 172.



Powdered GINGER adulterated with *Sago powder*.

a a, cells of ginger; *b b*, starch granules of ginger; *c c*, large yellow corpuscles analogous to those of turmeric; *d d*, fragment of woody fibre; *e e*, starch corpuscles of *sago meal*.

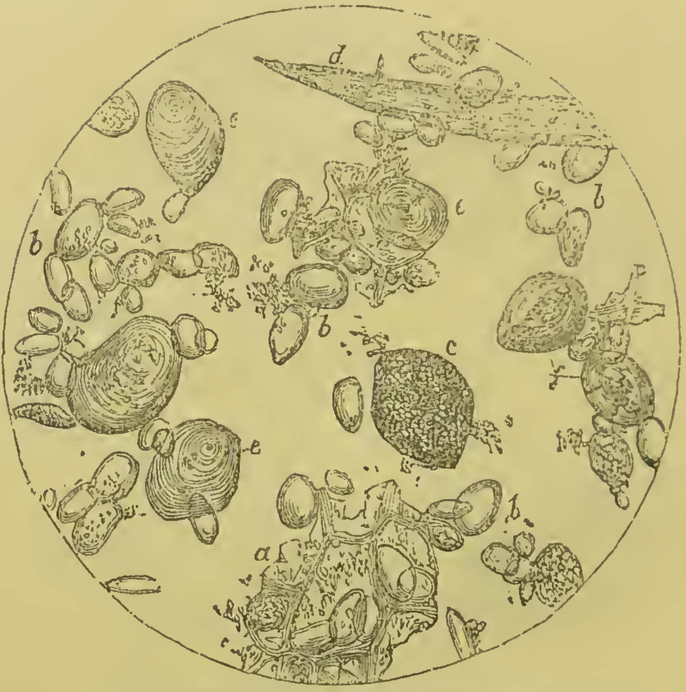
The Detection of the Adulterations of Ginger.

The whole of the substances employed in the adulteration of ginger may be detected with ease and certainty by means of the microscope. The microscopical characters of most of the articles used have already been described: as wheat flour, at p. 287; ground rice, at p. 307; potato flour, at p. 371; sago, at p. 375; turmeric, mustard husk, and Cayenne under their respective heads.

The structural peculiarities of Cayenne and mustard husk are so well marked that no difficulty whatever is experienced in identifying them when once seen under the microscope; but in those cases in which the quantities present are but small they are apt to be overlooked. It is advisable to wash away some of the starch from the portion of powder about to be placed under the microscope; by this means the larger particles are brought more clearly into view.

The adulteration with wheat flour is one which might readily escape detection. The observer is therefore cautioned before proceeding to the examination of powdered ginger to compare carefully the structural peculiarities of the starch granules of ginger and wheat flour; the differences, although not at first striking, are really considerable.

Fig. 173.



Powdered Ginger adulterated with *Potato* and *Sago starches.*

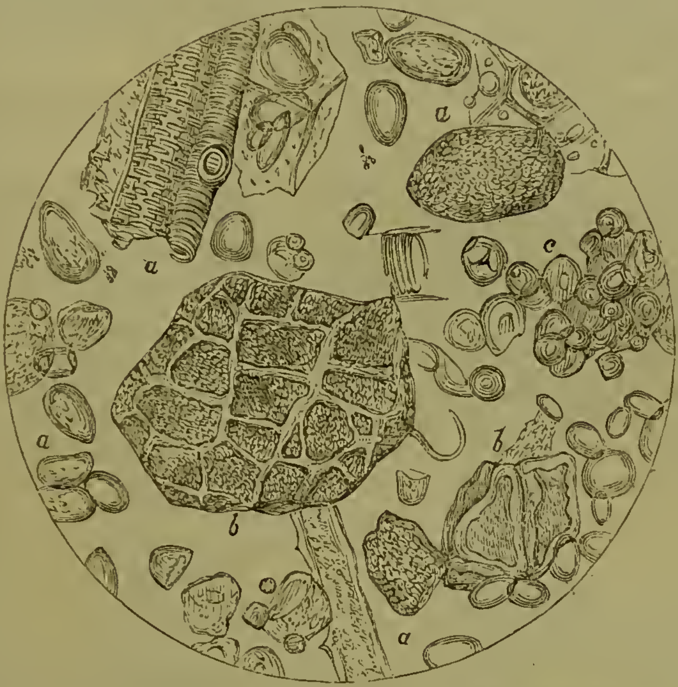
a a, cells of ginger; *b b*, starch granules of ginger; *c*, large yellow cell, analogous to those of turmeric; *d*, woody fibre; *e e*, starch granules of *potato*; *f f*, starch corpuscles of *sago*, altered by heat.

Since ginger contains yellow cells very closely resembling those of turmeric, we can only conclude that turmeric has been added when the number of such cells is much greater than in genuine powdered ginger.

The adulterations of ginger with sago and potato are exhibited in the two preceding engravings (figs. 172 and 173).

The engraving (fig. 174) represents the adulteration of powdered ginger with tapioca and Cayenne.

Fig. 174.



Powdered GINGER, *a a*; adulterated with *cayenne*, *b b*; and *tapioca*, *c c*. Magnified 200 diameters.

CINNAMON AND CASSIA AND THEIR ADULTERATIONS.

Cinnamon is the bark of the *Cinnamomum Zeylanicum*, one of the *Lauraceæ*, or laurel family, to which also belong Cassia and Camphor, as well as some other plants possessing medicinal properties, especially Clove bark.

Cinnamon is cultivated principally in Ceylon.

'The cinnamon bark of Ceylon is obtained by the cultivation of the plant. The principal cinnamon gardens lie in the neighbourhood of Colombo. The bark peelers or *choliahs*, having selected a tree of the best quality, lop off such branches as are three years old, and which appear proper for the purpose. Shoots or branches much less than half an inch, or more than two or three inches in diameter, are not peeled. The peeling is effected by making two opposite (or, when the branch is thick, three or four) longitudinal incisions, and then elevating the bark by introducing the peeling knife between it. When the bark adheres firmly, the separation is promoted by friction with the handle of the knife. In twenty-four hours the epidermis and greenish pulpy matter (rete mucosum) are carefully scraped off. In a few hours the smaller quills are introduced into the larger ones, and in this way a congeries of quills formed, often measuring forty inches long. The bark is then dried in the sun, and afterwards made into bundles with pieces of bamboo twigs.

'Cinnamon is imported in bales, boxes, and chests, principally from Ceylon, but in part also from Madras, Tellicherry, and rarely from Java and other places.

'In order to preserve and improve the quality of the bark, black pepper is sprinkled amongst the bales of cinnamon in stowing them at Ceylon (Percival). Mr. Bennet states that ships are sometimes detained for several weeks through the want of pepper to fill the interstices between the bales and the holds.

'When cinnamon arrives in London, it is unpacked and examined; all the mouldy and broken pieces are removed from it. It is then remade into bales. These are cylindrical, three feet six inches long, but of variable diameter, perhaps sixteen inches on the average. These bales are enveloped by a coarse cloth called *gunny*. The cinnamon in boxes and chests is usually the small, inferior, and mouldy pieces.'

Composition of Cinnamon.

The constituents of cinnamon are *volatile oil*, *tannin*, *mucilage*, *colouring matter*, partly soluble in water and alcohol, but not in ether, *resin*, an *acid*, *starch*, and *lignin*.

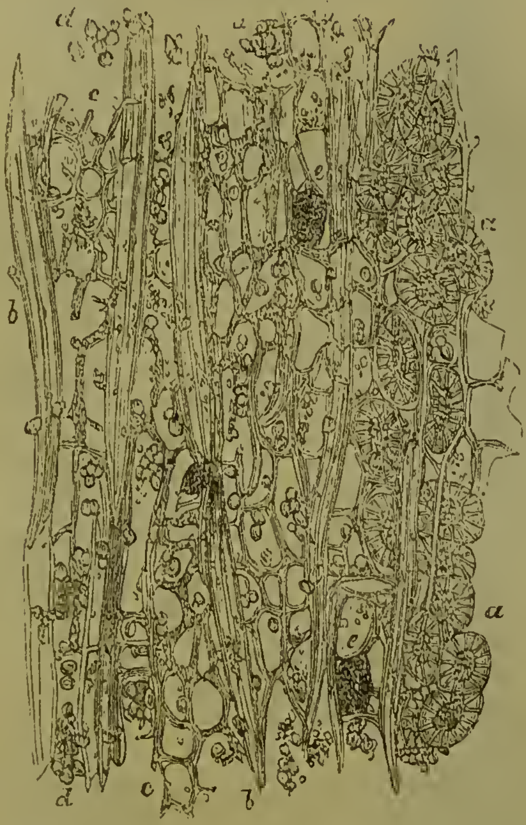
A decoction of cinnamon does not become blue on the addition of iodine; this is partly owing to the small quantity of starch present, and partly, it is supposed, to the presence of some principle (tannic acid?) which destroys the blue colour of the iodide of starch.

The cinnamon oil of commerce is derived from different trees of the genus cinnamomum. The oil is prepared by softening the bruised bark of *Cinnamomum zeylanicum* with salt water, distilling quickly, and drying with chloride of calcium. The oil consists chiefly of *cinnamic aldehyde*, which may be separated by means of acid sulphite of potassium, also of some *hydrocarbon* in very small quantity, together with *cinnamic acid* and *resins*. The density varies from 1·025 to 1·050, the boiling point 220° to 225° C. The older samples of the oil become coloured and contain much resinous matter, which remains after the oil has been distilled off with salt water. The salt is extracted with cold water and afterwards the cinnamic acid with boiling water. According to Mulder, two resins are formed by oxidation of the oil. With nitric acid it forms a white crystalline nitrate and a red oil, and with ammonia a solid crystalline amide is formed.

Structure of Cinnamon.

Cinnamon, under the microscope, presents a complicated and very distinct organisation, which is best seen in longitudinal sections, carried through the thickness of the bark.

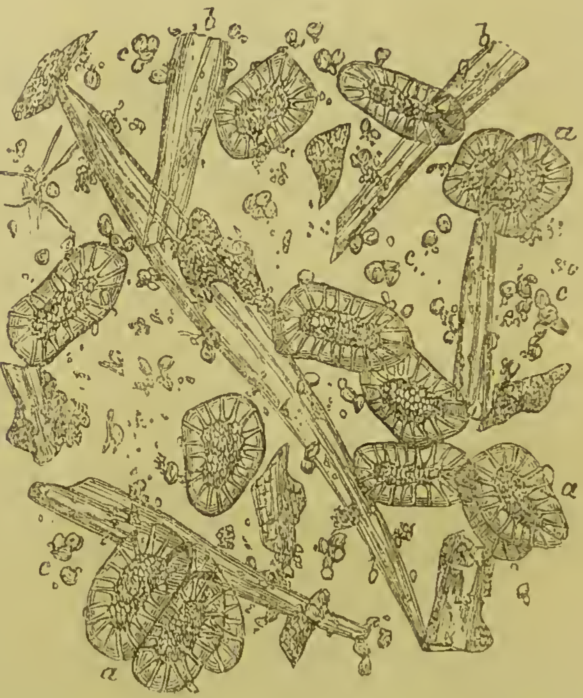
Fig. 175.



Longitudinal section of CINNAMON carried transversely through the bark, magnified 140 diameters.
a a, stellate cells ; *b b*, woody fibre ; *c c*, starch cells ; *d d*, starch granules ; *e e*, granular cinnamon-coloured cells or bodies.

On the outer or external surface of the section are observed numerous stellate cells, separable readily from each other, and similar to those which we have so often before described as occurring in other vegetable structures. These cells lie one upon the other in several layers, and form a considerable part of the thickness of the bark. They are situated in the intervals between the woody fibres; they are of a quadrangular or oval form, having the long axes placed usually transversely to the bark, their breadth being greater than their depth. In whatever position they are viewed, both the central cavities and the rays which proceed from them are visible. Occasionally, though not usually, a few starch granules may be seen in the cavities of these cells. Proceeding from without inwards, these cells are succeeded by others, which are distinguished from the first by the absence of rays, by the thinness of their walls, and by the firmness with which they adhere to each other; they generally contain a few starch corpuscles. These cells, which form several series, complete the thickness of the bark.

Fig. 176.



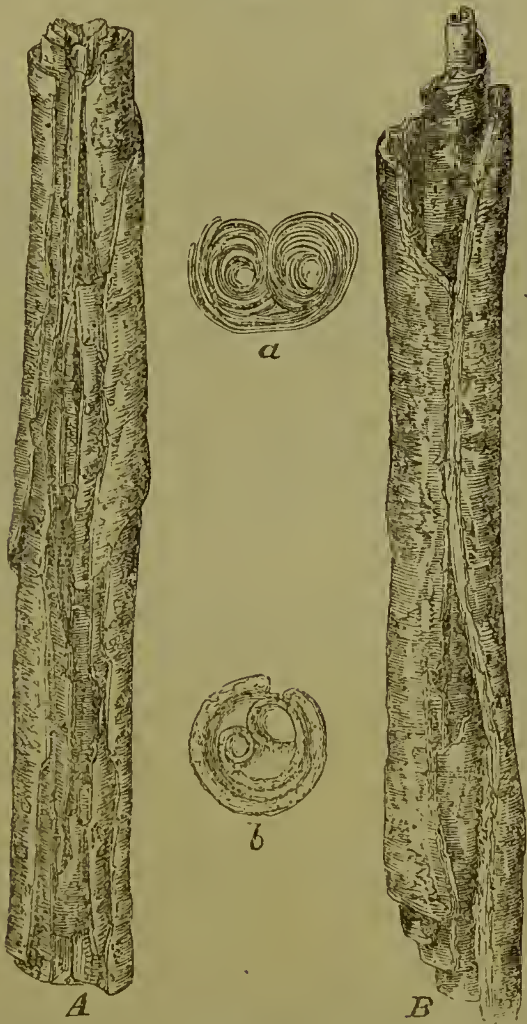
Genuine CINNAMON *powder*, magnified 220 diameters. *a a*, stellate cells; *b b*, woody fibre; *c c*, starch granules.

Interspersed between both the first and second kinds of cells are numerous woody fibres, which are rather short, pointed at either extremity, and furnished with a central canal. It is these which impart the fibrous character to cinnamon, particularly observable in fractures of the bark.

The starch corpuscles of cinnamon are small, more or less globular, and furnished with a very distinct hilum, which has the appearance of a central depression. They usually occur singly, but sometimes united in twos or fours.

Lastly, lying in the cavities of the most external of the second order of cells, are frequently to be observed deep cinnamon-coloured masses of granular texture.

Fig. 177.



A, Stick of Cinnamon of the natural size and appearance, showing the thinness of the bark, and the manner in which the layers are enclosed one within the other; *a*, cross section of same, exhibiting more completely the number of the layers, and their disposition.

B, Stick of Cassia of the natural size and appearance, showing the thickness of the bark, and the manner in which the layers are enclosed within each other; *b*, cross section of same, exhibiting the dispositions of the layers.

The above structural particulars are all shown in fig. 175.

In ground cinnamon the several structures are disunited and broken. The stellate cells occur singly, or in groups of two, three, or more; the woody fibre is disengaged, and is scattered about, resembling somewhat, in form and appearance, the hairs which occur on many plants; the starch corpuscles are set free from their cells; and, lastly, the cinnamon-like masses may be seen in the field of the microscope, dispersed here and there (fig. 176).

Composition and Structure of Cassia.

Cassia, *Cinnamonum cassia*, belongs to the same genus of plants as the true cinnamon, and hence it resembles it very closely in its composition and structure.

Composition of cassia.—Since cassia is so frequently substituted for cinnamon, it becomes necessary that we should acquaint ourselves with its composition and structure.

If tincture of iodine is added to a decoction of cassia, it turns blue, owing to the larger proportion of starch contained in it.

Oil of cassia possesses nearly the same properties as oil of cinnamon; it is said to be a thicker and heavier oil than that of cinnamon; and its odour and flavour are inferior.

Structure of cassia.—Notwithstanding the striking resemblances, between cassia and cinnamon, there are characters, however, by which they may be discriminated.

The bark of cinnamon is scarcely thicker than drawing-paper, and breaks with an uneven and fibrous margin; while each stick consists of eight, ten, or more pieces or *quills* of bark inserted one within the other.

Cassia bark is much stouter, being often as thick as a shilling; it breaks short, and without splintering. By these characters alone it is easy to distinguish cinnamon from cassia when in the whole state, as shown by the accompanying drawing (fig. 177).

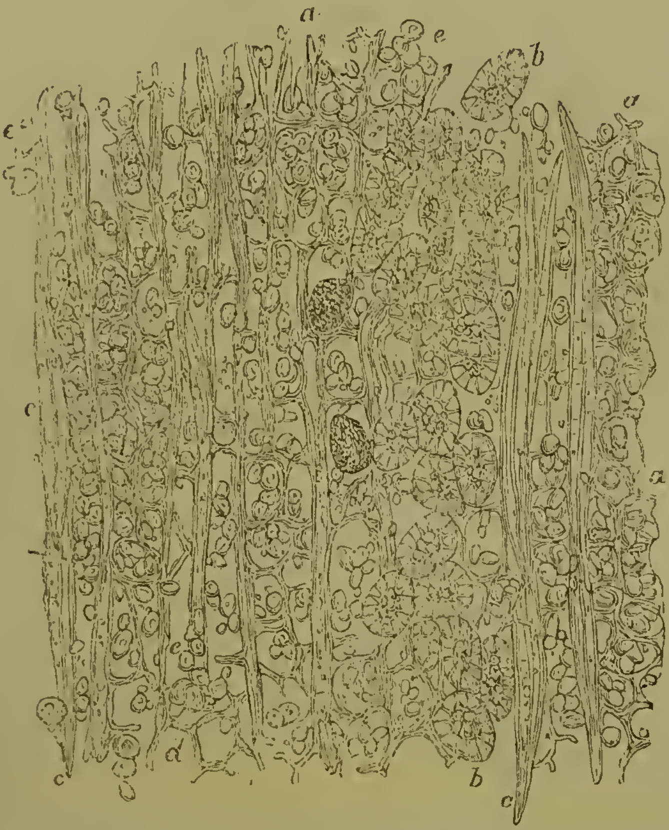
But these barks differ also in colour and taste. Cinnamon is paler and browner than cassia, which is ususally redder and brighter. The taste of one is sweet, mild, and aromatic, leaving no unpleasant impression on the tongue, while that of the other is less sweet, stronger, and is followed by a bitterness.

These characters, however, vary in different samples, so that it is impossible by these means alone to distinguish cinnamon from cassia when in powder, and we are not aware that any certain means have been pointed out for effecting the discrimination, especially when the two are mixed in different proportions; but here again, as in so many other cases, the microscope affords us invaluable assistance.

Sections of cassia bark, viewed under the microscope, bear a close general resemblance to those of cinnamon, but differ in their greater width and the relative proportions of the several structures, particularly in the size and number of the starch corpuscles (fig. 178).

We observe on the outer surface, as in cinnamon, the peculiar stellate cells, the cavities of which, however, much more commonly than those of cinnamon, are filled with well-developed starch corpuscles.

Fig. 178.



Longitudinal section of CASSIA, carried transversely through the bark, magnified 140 diameters.
a a, cells of epidermis; *b b*, stellate cells; *d d*, starch cells; *e e*, starch granules; *f f*, granular cinnamon-coloured masses.

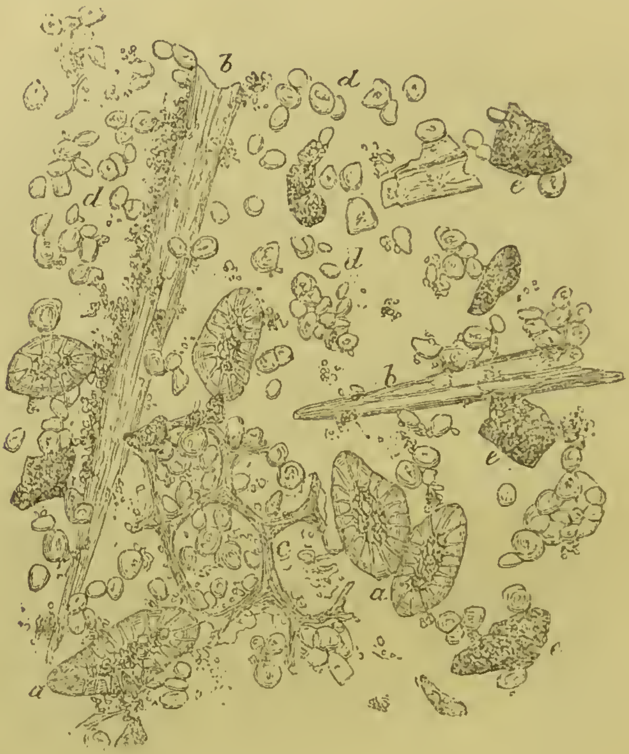
Lying next to these, we notice what may be termed the proper starch cells, usually crammed quite full of starch corpuscles, which, while they have the same general form as those of cinnamon, are yet two or three times larger, as well as many times more numerous.

The woody fibre occurs, as in cinnamon, interspersed between both descriptions of cells, and it does not appear to differ appreciably from that of cinnamon.

Of the entire thickness of the bark, about one-fourth is formed by the stellate cells; the remaining three-fourths being made up of the starch-bearing cells.

In powdered cassia, therefore, as contrasted with powdered cinnamon, the stellate cells and woody fibre are much less abundant, while the starch granules are at the same time much larger, and far more numerous (fig. 179).

Fig. 179.



Genuine CASSIA *powder*, magnified 220 diameters; *a a*, stellate cells; *b b*, woody fibre; *c c*, starch cells; *d d*, starch granules; *e e*, granular masses.

The Adulterations of Cinnamon and Cassia.

From an examination of the analyses of *thirty-two* samples of cinnamon, it appeared that of the twelve *whole* cinnamons, *seven* were *genuine*, and that *five* consisted of nothing but *cassia*.

That the *essential oil* is sometimes abstracted, and the bark, after being reduced, sold either whole or in the ground state.

That of the *nineteen* samples of *ground* cinnamon, *three* consisted entirely of *cassia*.

That *ten* of the samples, or more than one-half, were *adulterated*, the articles most frequently employed being either *baked wheat flour* or *sago meal*, separately or in combination, but *East India arrowroot* and *potato flour* were likewise detected each in one instance.

That of the above adulterated samples *three* consisted of *cassia* adulterated, and *seven* of *cinnamon* adulterated.

That *six* only of the *nineteen* samples were *genuine*.

In the prices charged for the samples of cinnamon examined, whether whole or in powder, genuine or adulterated, no constant difference was to be observed, and consequently the public suffers great loss by the substitution of cassia, which is so much cheaper, for cinnamon, and a still greater loss by the other sophistications.

The wheat flour and sago detected were generally baked, to make them resemble in colour more nearly ground cinnamon or cassia, and thus the better escape detection.

The Detection of the Adulterations of Cinnamon and Cassia.

The detection of the various adulterations of cinnamon and cassia is, in nearly all cases, easy enough by means of the microscope; all that is requisite is that the observer should be acquainted with the structure and characters of genuine cassia and cinnamon, as well as of the articles employed to adulterate them.

The mixture of cassia with cinnamon of course constitutes an adulteration, but very frequently cassia is substituted for cinnamon. The mixture and substitution are both discoverable with the microscope by the difference in the size of the starch granules, but the substitution may be detected in other ways.

Thus when stick cassia is substituted for cinnamon, the substitution is known by the greater thickness of cassia bark.

Again, the decoction of cassia bark turns blue on the addition of iodine, when one of cinnamon similarly treated does not become blue.

It is stated that the oil is sometimes removed from cinnamon bark, this being subsequently ground to powder and mixed with genuine cinnamon.

This fraud may be discovered in two ways: the suspected cinnamon may be boiled in distilled water for a time and the oil distilled off; the quantity of oil obtained may be estimated by measurement in a small graduated tube rather than by weighing.

A more expeditious process is to examine the cinnamon with the microscope; if this has been acted upon by boiling water, the starch granules will be found to have lost their proper form, to have become distorted and irregular, while many of them are larger than natural. If the cinnamon has been subjected to the prolonged action of the water, the granules will have become so broken up and dissolved that they can no longer be detected.

NUTMEGS AND THEIR ADULTERATIONS.

There are three species of *Myristica* which furnish nutmegs. That which yields the best description, *Myristica fragrans*, forms a tree from twenty to twenty-five feet high, somewhat similar in appearance to a pear tree.

The fruit is smooth externally, pear-shaped, and about the size of an ordinary peach. It consists, first, of an outer fleshy covering, called the *pericarp*, which when mature separates into nearly equal longitudinal parts, or valves; secondly, of the *aril*, or *mace*, which, when recent, is of a bright scarlet colour; and thirdly, of the seed proper, or *nutmeg*. This is enclosed in a shell, which is made up of two coats: the outer is hard and smooth; the inner, thin, closely invests the seed, sending off prolongations, which enter the substance of the seed, and which, being coloured, impart the marbled or mottled appearance characteristic of nutmeg.

There are two kind of nutmegs met with in commerce. The first, called the *true*, *round*, *cultivated*, or *female* nutmeg, is the product of *Myristica fragrans*.

The second kind of nutmeg is called the *false*, *long*, *wild*, or *male* nutmeg, and is the produce chiefly of *Myristica fatua*; but a kind of nutmeg which is also called wild, is obtained from *Myristica Malabarica*.

In the Banda Islands, three crops or harvests of nutmegs are obtained in the year; the principal gathering is in July or August; the second in November; and the third in March or April.

The fruit is gathered by means of a barb attached to a long stick: the mace is separated from the nut, and separately cured.

On account of their liability to the attacks of an insect known as the *nutmeg insect*, considerable care is required in drying them. They should be dried in their shells, as they are then secure from the insect. They are placed on hurdles, and smoke-dried over a slow wood fire for about two months. In the Banda Islands, they are first dried in the sun for a few days. When the operation of drying is complete, the nuts rattle in their shells; these are cracked with mallets, and the damaged, shrivelled, or worm-eaten nuts removed.

'To prevent the attacks of the insect, the nuts are frequently limed. For the English market, however, the brown or unlimed nutmegs are preferred. The Dutch lime them by dipping them into a thick mixture of lime and water; but this process is considered to injure their flavour. Others lime them by rubbing them with recently-prepared, well-sifted lime. This process is sometimes practised in London.'—*Pereira.*

Composition of Nutmegs.

Nutmegs contain both a fixed and a volatile oil. The *fixed oil* or *myristin* is prepared by beating the nutmegs to a paste; this is subjected, enclosed in a bag, to the vapour of water, and the oil afterwards expressed by means of heated plates. It is imported in cakes which have somewhat the size and form of common bricks, and are covered with leaves. The fixed oil procured in this manner contains a portion of the volatile oil, from which its colour and fragrant odour are derived.

The *volatile oil*, on the presence of which the flavour and aroma of nutmegs principally depend, is procured by distillation with water; the produce thus obtained at Apothecaries' Hall, London, is usually 4·5 per cent., but according to most observers nutmegs contain about 6 per cent. This oil has a specific gravity according to Lewis, of 0·948, and according to Bley, 0·920. It is a mixture of a volatile oil and a camphor. When left to stand, it deposits *myristicin*, which is readily soluble in boiling water, crystallising on cooling in long very thin prisms with dihedral summits or in stellæ. It melts at above 100° C. and sublimes at a higher temperature. Now, nutmegs are frequently deprived of a portion of their essential oil by distillation, and after being well limed, are again sent into the market in this comparatively valueless state.

Bonastre's analysis.

Volatile oil	6·0
Liquid fat	7·6
Solid fat	24·0
Acid	0·8
Starch	2·4
Gum	1·2
Ligneous fibre	54·0
Loss	4·0
	100·0

Structure of Nutmegs.

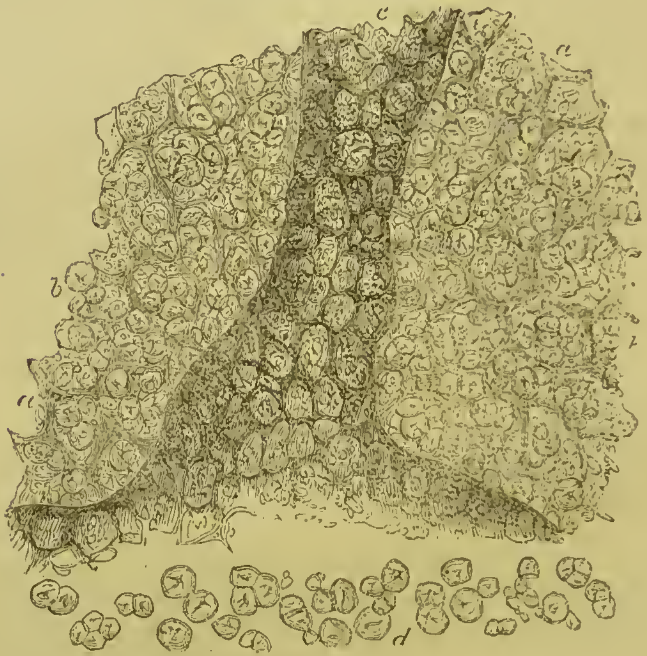
Nutmegs under the microscope present peculiarities of structure, by which they may be distinguished, even in powder, from other vegetable productions. A thin section, viewed under an object glass magnifying 220 diameters, is seen to consist of minute angular cells. Those forming the white or *uncoloured* part of the nut present, previous to the action of water upon them, an opalescent appearance, from the quantity of oil enclosed in them; their cavities contain in addition much starch, in the form of small but distinct granules, mostly of a rounded shape; but occasionally a few of the granules are angular; and all have well-marked central depressions.

The cells forming the *coloured*, vein-like portion of the nut differ from the other cells in colour and in being destitute of starch, containing apparently only a small quantity of oil (fig. 180).

The Adulterations of Nutmegs.

Since nutmegs are never sold in the powdered state, they are not liable to adulteration by admixture with foreign ingredients, like several of the spices which have been already noticed, as ginger, cinnamon, and cassia; nevertheless, they are subjected to a process which impairs their value and quality as much as though they had been actually adulterated in the same manner as by the abstraction of the volatile oil.

Fig. 180.
SECTION OF NUTMEG.
(Magnified 220 diameters.)



a a, cells forming the white or uncoloured portions of the nutmeg; they are seen to contain numerous starch granules. *b b*, the starch granules. *c*, a portion of one of the veins formed by the inversion of the inner coat of the seed vessel or *endopleura*; it consists of coloured cells, containing oil only. *d*, loose starch granules magnified 420 diameters.

The wild nutmeg obtained from the *Myristica Malabarica* has scarcely any flavour or odour, and according to Rheede, is of the size and figure of a date. 'The Turkish and Jewish merchants,' writes Rheede, 'mix these nutmegs with the true long ones, and the mace with good mace, selling them together. They also extract from these inferior articles an oil, with which they adulterate that of a more genuine quality.'

The work of M. Chevallier, entitled 'Dictionnaire des Altérations et Falsifications des Substances Alimentaires, Médicamenteuses, et Commerciales,' in treating of nutmegs, contains the following observations, under the head of 'Falsifications:'—

'Nutmegs are sometimes mixed with riddled nuts, eaten by insects, and become brittle; the small apertures are then closed with a kind of cement, formed of flour, oil, and the powder of nutmegs. This paste has even served to fabricate false nutmegs, inodorous and insipid. The workmen of Marseilles have even made them of bran, clay, and the refuse of nutmegs: these nutmegs, placed in contact with water, soften down in that liquid.

'The worm-eaten nuts are equally insipid, and almost inodorous; sometimes they have a mouldy odour.'

Eighteen samples of nutmegs were subjected to examination, the result being that *in no case had the essential oil been abstracted.*

The Detection of the Adulterations of Nutmegs.

The only adulteration, excepting that by admixture with wild nutmegs, to which it appears that nutmegs are liable—and this doubtless is of rare occurrence—is by means of the artificial or factitious nutmegs mentioned by M. Chevallier.

These may be readily discovered by soaking them in water, when, of course, they would readily break down.

The differences between the cultivated and wild nutmegs have already been described.

The nutmegs from which the oil has been abstracted may be recognised by the presence of punctures on the surface, and by their much greater lightness.

It is singular that the starch granules of nutmeg are but little affected by boiling; so that this means of discrimination, so satisfacory in the case of cinnamon, cassia, and some other spices, is of little or no value in the present instance.

Of this remarkable circumstance it is not easy to afford an explanaion; it probably depends upon the difficulty with which the boiling water makes its way into the substance of the nut, in consequence of ts hard texture and the large quantity of fixed oil contained in it.

The differential duties on wild and cultivated nutmegs offer a premium for the substitution of the inferior for the superior article.

MACE AND ITS ADULTERATIONS.

As there are two kinds of nutmeg, so are there two kinds of mace, he produce of the same plants: thus, there is true or cultivated mace, and false or wild mace.

Wild or false mace is of a dark-red colour, and deficient in flavour and aroma.

Composition.

The composition of mace closely resembles that of the nutmeg itself; it contains, as will be seen from the following analysis, a volatile and a fixed oil—

Volatile oil.
Red fat oil, soluble in alcohol.
Yellow fat oil, insoluble in alcohol.
Alcoholic extractive.
Amiden.
Ligneous fibre with lime.

Structure of Mace.

Viewed under the microscope, mace presents a structure very distinct from that of the nutmeg itself.

Covering the surface of the blades is a delicate membrane, consisting of a single layer of cells; they are tubular, much elongated, taper at either end to a point, and resemble in size and form, although not in delicacy of texture, ordinary woody fibre. The long diameters of the cells are disposed vertically on the surface of the mace.

But the chief substance is made up of other cells differing in size and form from those already noticed; these contain fixed oil, and much starch.

Imbedded in the midst of these cells are larger cells, spaces, or *receptacles*, which, in thin sections, whether made crosswise or lengthwise, appear as apertures. These contain the essential oil of mace.

Scattered here and there may be seen, both in transverse and longitudinal sections, small bundles of woody fibre, of a brownish colour, enclosing one or two small spiral vessels. In transverse sections the ordinary starch cells are perceived to be arranged round the bundles in a radiate manner.

The structure of mace is exhibited in fig. 181.

The Adulterations of Mace.

Like the nutmeg, mace may be deprived, by distillation, of its essential oil.

The only adulteration of mace known to be practised is that by admixture with wild mace; this is distinguished by its dark red colour and by its deficiency in flavour and aroma.

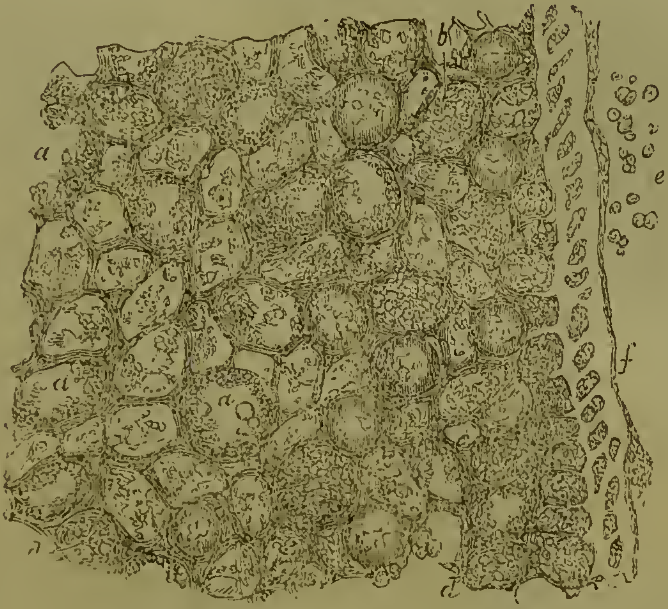
Of *twelve* samples of mace subjected to examination *the whole were genuine.*

CLOVES AND THEIR ADULTERATIONS.

Cloves are the unexpanded flower-buds of *Eugenia caryophyllata* or *Caryophyllus aromaticus*, a tree from fifteen to thirty feet in height, one of the Myrtaceæ or myrtle tribe. The word *clove* is derived from the French word *clou,* from a fancied resemblance to a nail in the form of the clove.

The flower-buds are arranged on terminal flower-stalks; they are either gathered by hand or obtained by beating with bundles of reeds, in which case cloths are spread beneath the trees to catch them; they are afterwards dried either by the fire, or, what is better, in the sun; they are imported in casks or bags.

Fig. 181.
Transverse Section of Mace.
(Magnified 220 diameters.)



a a, receptacles for the essential oil; many of them appear in the section as apertures, and are represented in the figure as such. *b b*, the same, exhibiting the appearance of closed cells, from the circumstance of their not being cut into; the colouring matter of mace is located chiefly in these cells or receptacles. *c c*, large air-bubbles usually observed in sections immersed in water. *d d*, cells filled with starch corpuscles. *e*, the starch corpuscles loose, magnified 420 diameters. *f*, the cells forming the delicate coat or cuticle investing mace.

Composition of the Clove.

Cloves contain, according to the analysis of Trommsdorf, *volatile il*, 18; *almost tasteless resin*, 6; *tannin*, 13; *difficultly-soluble extrac-ive with tannin*, 4; *gum*, 13; *woody fibre*, 28; and *water*, 18 per cent. The volatile oil is obtained from cloves by repeated distillation.

The yield on an average is said to be from seventeen to twenty-two per cent.

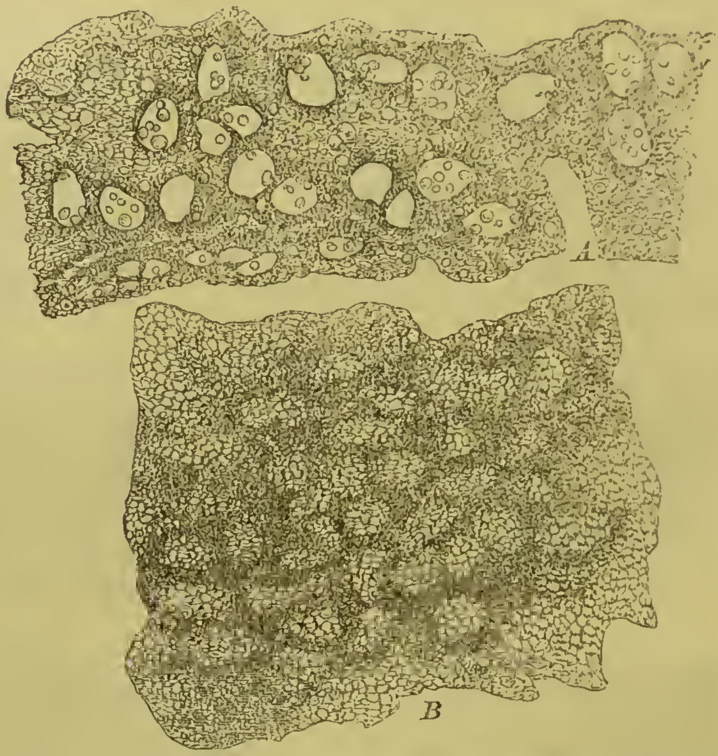
It has been ascertained that the oil, which was formerly regarded as a simple oil, is really composed of two volatile oils, possessing different qualities, and one of which is lighter and the other heavier than water.

The characters and composition of these oils are thus given in Pereira's 'Materia Medica,' ed. 1. part ii. p. 1093:—

Fig. 182.

Petal of Clove-bud.

(Magnified 60 diameters.)



A, transverse section of the petal of flower-bud of clove, showing the receptacles in which the essential oil is contained. *B*, surface of petal; the receptacles for the oil in this view are indistinct.

a. Light Oil of Cloves (*Clove-Hydrocarbon*).—Colourless, sp. gr. 0·918, at 18° C., boils at from 142 to 143° C. It passes over with the vapour of water when the crude oil of cloves is distilled with potash. Incapable of combining with bases, but absorbing hydrochloric acid gas without yielding a crystalline compound. It consists of $C_{10}H_{16}$; hence it is isomeric with oil of turpentine.

β. *Heavy Oil of Cloves* (Clove Acid; Eugenic Acid).—When crude oil of cloves is distilled with potash, the clove hydrocarbon, sometimes called the light oil of cloves, passes over, eugenic acid remaining behind as a eugenate of potash from which it may be separated by a mineral acid. It is colourless when recently prepared, but becomes coloured by age with the formation of resins. Its specific gravity, according to Stenhouse, is 1·076, and its boiling point 242° C. Its formula is $C_{10}H_{12}O_2$. It combines with alkalies to form crystalline salts (*alkaline eugenates, clove-oil alkalies*). If a salt of iron be added to one of these, it yields a blue, violet, or reddish compound (*a ferruginous eugenate*), varying somewhat according to the nature of the ferruginous salt used; thus the protosulphate of iron yields a lilac, the persulphate a red, which becomes violet and afterwards blue; while the sesquichloride gives a vinous, which turns to red (Bonastre). Nitric acid reddens clove acid.

A substance which crystallises in white nacreous laminæ is frequently deposited from the water distilled from cloves. This has been called *clove-camphor* or *eugenin*, and is said to be isomeric with eugenic acid. It is insoluble in water, and with nitric acid turns blood-red.

The unexpanded flower-buds are not the only parts of the tree which are aromatic, as the footstalks and fruit or seed vessels are likewise so to some extent.

The peduncles, or *footstalks*, according to Guibourt, are sometimes substituted for cloves by distillers of the oil.

The fruit, *mother-cloves* as they have been called, are occasionally met with in commerce; they have the shape of the olive, but are smaller, and possess the odour and taste of the clove in a mild degree.

Structure of the Clove.

The minute structure of cloves is extremely characteristic. The rounded head or *bud* consists of the unexpanded petals; if a transverse section of one of these be made, it will be seen to be composed of cellular tissue, in the midst of which are numerous receptacles for the essential oil; these extend through the whole thickness of the leaf, being usually three or four deep.

When the petal is viewed on the surface, the receptacles are seen but indistinctly, being obscured by the cellular tissue of which the surface of the petal is formed (fig. 182).

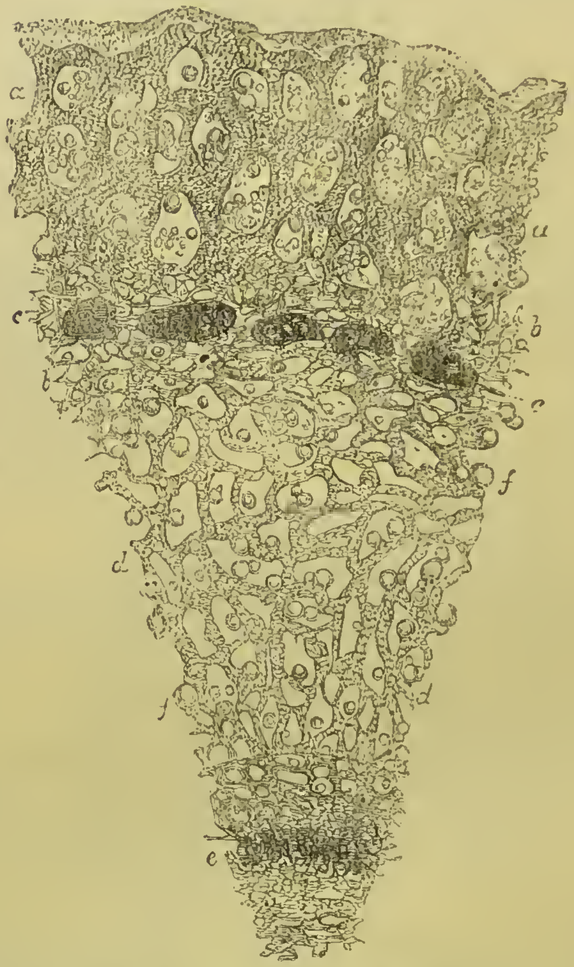
In a transverse section of the *flower-stalk*, viewed with an object-glass of one-inch focus, the following appearances present themselves:—

In the outer third of the section, numerous large holes are observed; these are the divided receptacles; next to these, passing inwards, are bundles of woody fibre, forming a narrow circle in the interior of the stalk; extending from these to near the centre of the stalk is a tissue formed of numerous tubular cells, with large spaces between them. The receptacles, as well as the tubular cells and interspaces, contain essential oil, visible in sections immersed in water, in the form of innumerable droplets (fig. 183).

Fig. 183.

Transverse Section of Flower-stalk of the Clove.

(Magnified 60 diameters.)



a, receptacles for the essential oil; the section being a thin one, they present the appearance of apertures, in consequence of being opened into. *b b*, cellular tissues surrounding the woody fibre. *c c*, bundles of woody fibre. *d*, the tubular structure and interspaces, of which the internal portion of the stalk is formed. *e*, the centre of the stalk; it appears dark under the microscope, the structure being obscure. *f f*, droplets of oil.

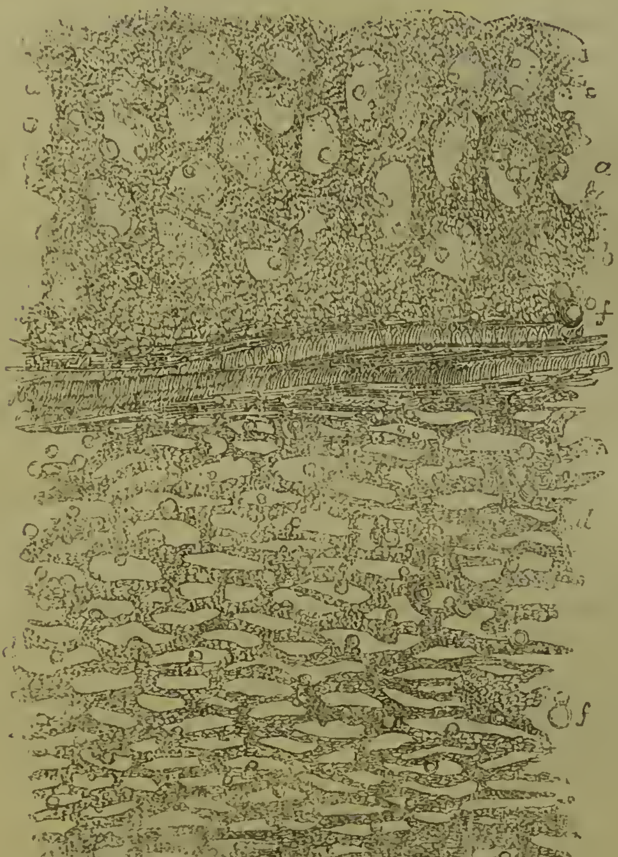
Longitudinal sections exhibit a nearly similar structural arrangement (fig. 184).

Cloves contain scarcely any starch.

Fig. 184.

LONGITUDINAL SECTION OF FLOWER-STALK OF THE CLOVE.

(Magnified 60 diameters.)



a a, receptacles for the essential oil, appearing as apertures from having been cut into in making the section. *b*, cellular tissue. *c*, woody fibre. *d*, the tubular structure and interspaces which form the internal portion of the stalk. *e*, the dark central part of the flower-stalk. *f f*, droplets of oil.

The clove-stalks present a structure somewhat similar to that of cloves themselves; that is, they consist of cellular tissue, hollowed out here and there into receptacles for the essential oil; but, in addition, the stalks are provided with an epidermis, or coating of the stellate cells, which are of such frequent occurrence in different kinds of bark.

The Adulterations of Cloves.

Cloves are but seldom sold in powder, and hence the liability to adulteration is greatly lessened; they are, however, occasionally met with in that state.

Clove-stalks, although very inferior, contain some of the active properties of cloves, and, as already noticed, are occasionally used by distillers for procuring the essential oil of cloves. We have reason to believe that in some cases the stalks are ground up, and mixed with the powder of genuine cloves.

The quality and value of cloves are not unfrequently impaired, like some other spices, by the abstraction of the essential oil.

This fraud used to be extensively practised in Holland, the *drawn* cloves, for more effectual concealment, being mixed with others of good quality; and even in some instances the trouble was taken to restore as nearly as possible to the exhausted cloves their original appearance, by rubbing them over with some common oil.

Twenty-five samples of cloves, whole and in powder, were subjected to examination, the results being that *one* only of the powdered cloves contained a proportion of clove-stalks, while from none of the whole cloves had the essential oil been abstracted.

The volatile oil, as imported into this country from India, has been found to be adulterated.

Mr. M'Culloch, on the authority of Milburn, states that the oil imported from India contains nearly half its weight of an insipid expressed oil, which is discovered by dropping a little into spirits of wine, and on shaking it the genuine oil mixes with the spirit, and, the insipid separating, the fraud is detected.

Cloves readily imbibe moisture, whereby their weight becomes greatly increased, a fact of which dishonest dealers have not failed to avail themselves.

The Detection of the Adulterations of Cloves.

The adulteration of powdered cloves with clove-stalks is readily detected by means of the microscope, which reveals the presence of the stellate cells of the stalk. If the essential oil has been removed, the cloves will be dry and bitter, no oil appearing on the surface when the cloves are pressed with the nail.

The quantity of essential oil may be estimated by distillation: genuine cloves yield from 17 to 22 per cent. of oil.

Adulterations with foreign vegetable substances are all discovered by the microscope.

PIMENTO OR ALLSPICE AND ITS ADULTERATIONS.

Pimento, Jamaica pepper, or Allspice, is the berry or fruit of the *Myrtus pimento* or *Eugenia pimento*, one of the *Myrtaceæ*. It grows in the West Indies, and principally in Jamaica, especially on the hills on the north side of that island. It forms a beautiful tree, which attains some thirty feet in height, and is planted in regular walks, which are named *Pimento walks.*

The fruit is gathered after it has attained its full size, but while still green; it is usually sun-dried, but sometimes kiln-dried on sheets; in drying, the colour of the fruits change from green to reddish-brown; when ripe, the berry becomes black or dark purple in colour, and is glutinous, and consequently in that state unfit for preservation.

Composition of Allspice.

As in the case of cloves, the essential oil of pimento is a mixture of two oils—a light and a heavy oil. The properties of these are thus described in Pereira's 'Materia Medica':—

'By distillation with water, allspice, like cloves, yields two volatile oils—the one lighter, the other heavier than water. The oil of pimento of the shops is a mixture of these; except in odour, its properties are almost identical with those of oil of cloves. Its specific gravity at 8° C. is 1·03. By distillation with caustic potash, the *light oil* is separated; the residue, mixed with sulphuric acid, and submitted to distillation, gives out the heavy oil.

'*a. Light oil of pimento* (*Pimento-Hydrocarbon*) has not, to my knowledge, been previously examined. Its properties appear to be similar to those of the light oil of cloves. It floats on water and on liquor potassæ, and is slightly reddened by nitric acid. Potassium sinks in, and is scarcely, if at all, acted on by it.

'*β. Heavy oil of pimento* (*Pimentic Acid*).—Very similar to clove-acid. It forms with the alkalies crystalline compounds (*alkaline pimentates*), which become blue or greenish on the addition of the tincture of the chloride of iron (owing to the formation of a *ferruginous pimentate*). Nitric acid acts violently on and reddens it.' The heavy oil is said by some to be identical with eugenic acid.

Bonastre,[1] in 1825, published the following analysis of the composition of pimento berries:—

---

[1] 'Journ. de Chim. Méd.' i. 210.

	Husks.	Kernels.
Volatile oil	10·0	5·0
Green oil	8·4	2·5
Solid fat oil	0·9	1·2
Astringent extract	11·4	39·8
Gummy extract	3·0	7·2
Colouring matter	4·0	—
Resinous matter	1·2	—
Uncrystallisable sugar	3·0	8·0
Malic or gallic acid	0·6	1·6
Lignin	50·0	—
Saline ashes	2·8	1·9
Water	3·5	3·0
Loss	1·6	1·8
Red matter insoluble in water	—	8·8
Pellicular residue	—	16·0
Brown flocculi	—	3·2
Total	100·0	100·0

Complicated and complete as the above analysis would appear to be, it yet does not embrace the starch which is contained in the seeds in large quantity. Braconnet, however, detected the presence of starch, and estimates it as forming 9 per cent. of the seeds.[1]

Mr. Whipple estimates the yield of pimento oil to be about 4·37 per cent. of the weight of the seed.

Structure of Allspice.

As in the case of other seeds, the pimento berry is divisible into husk and seed, or seeds proper.

The husk is thick, and, when dried, soft and brittle; it sends off from its inner surface a prolongation which forms a septum, and divides the interior into two parts or cells.

Vertical sections of the *husk*, viewed under the microscope, present the following structures:—

On the outer part of the section are seen several large cells or *receptacles* for the essential oil, sometimes two or three deep; more internally, numerous stellate cells, attached to and imbedded in cellular tissue, occur; next to these are bundles of woody fibre and delicate spiral vessels; while the deepest or innermost part of the section consists of cellular tissue only.

Occupying each of the cells formed by the husk is a small flattish seed of a dark brown or chocolate colour. After maceration, two membranes may be separated, although with some difficulty, from the surface of the seed. The most external of these is thin and delicate, and consists of a single layer of elongated and angular cells. The internal tunic is composed of several layers of large corrugated and coloured cells; it is to these that the dark colour of the surface of the seed is due; when viewed under the microscope, they exhibit a characteristic port wine tint (figs. 185 and 186).

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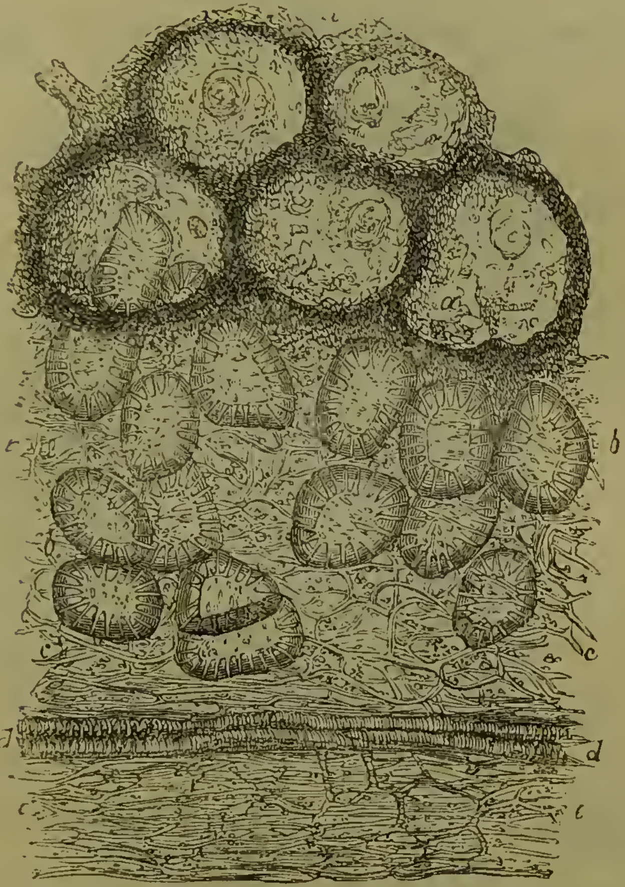
[1] Duncan, 'Edinb. Dispens.'

Fig. 185.

Vertical Section of Husk of Pimento Berry.

(Magnified 220 diameters.)



a, cells or receptacles for the essential oil. *b*, stellate cells. *c*, cellular tissue surrounding the stellate cells. *d*, bundles of woody fibre and spiral vessels. *e*, cellular tissue forming the innermost part of the section.

The structure of the *seed* proper, as displayed in vertical sections, is as follows:—

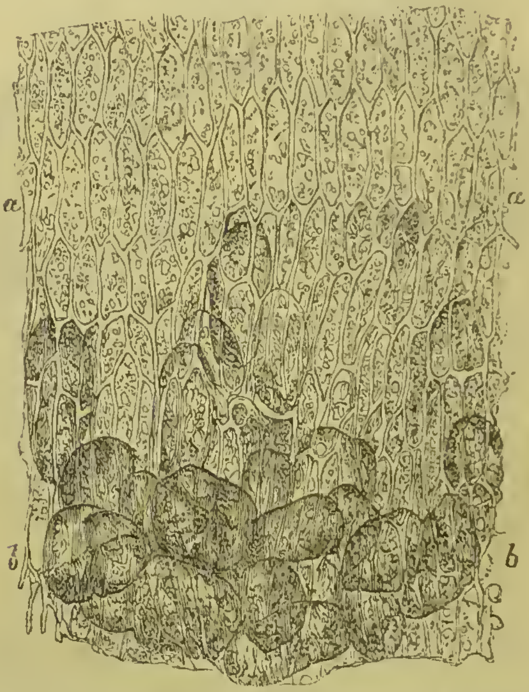
Running round the outer part of the section is a single layer of large receptacles, the remaining thickness being made up of angular and transparent cells, the cavities of which are filled with numerous well-defined starch granules (fig. 187).

When pimento berries are reduced to powder, the whole of the foregoing structures become disunited, broken up, and variously intermixed. The port-wine coloured cells are particularly conspicuous, and afford a character by which the nature of the powder may be at once determined.

Fig. 186.

Portion of the Membranes on Surface of the Seed Proper.

(Magnified 220 diameters.)



a. External membrane, consisting of a single layer of elongated and angular cells. *b.* Internal membrane, made up of several layers of large port wine coloured cells.

The several structures above mentioned, as they appear in genuine ground pimento powder or allspice, are represented in fig. 188, p. 586.

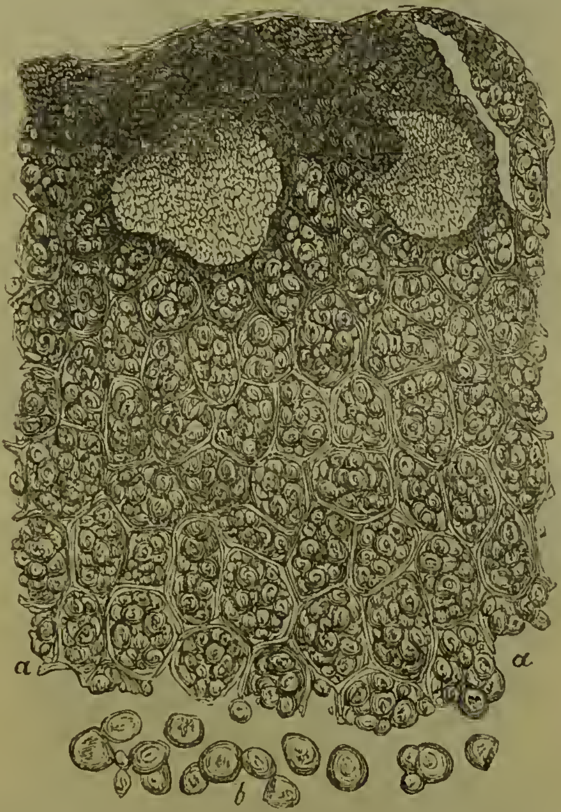
The Adulterations of Allspice.

Of *twenty-one* samples of ground allspice subjected to examination, one only was adulterated with *mustard husk*, a result probably mainly attributable to the great cheapness of this spice.

Fig. 187.

Vertical Section of the Seed Proper of Pimento Berry.

(Magnified 220 diameters.)



In the upper part of the figure two of the *receptacles* for the oil are exhibited; and in the lower part, *a a*, the cells containing the small rounded starch corpuscles; *b*, loose starch corpuscles, magnified 420 diameters.

The Detection of the Adulterations of Allspice.

The adulteration with mustard husk is one which is very readily discoverable by means of the microscope, the structural peculiarities of which will be found described under the article 'Mustard.'

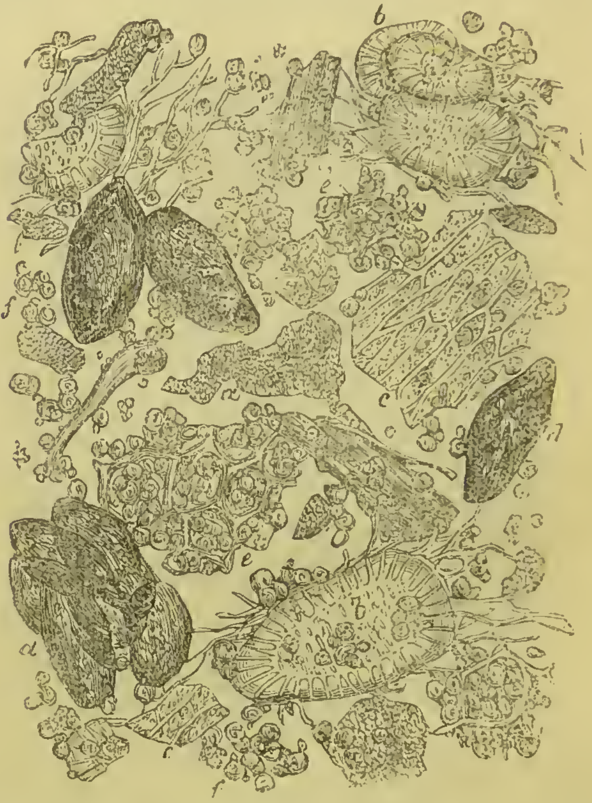
MIXED SPICE AND ITS ADULTERATIONS.

Mixed spice, as the name implies, is a mixture in different proportions of several spices; those of which it is usually composed are

Fig. 188.

Ground Pimento or Allspice.

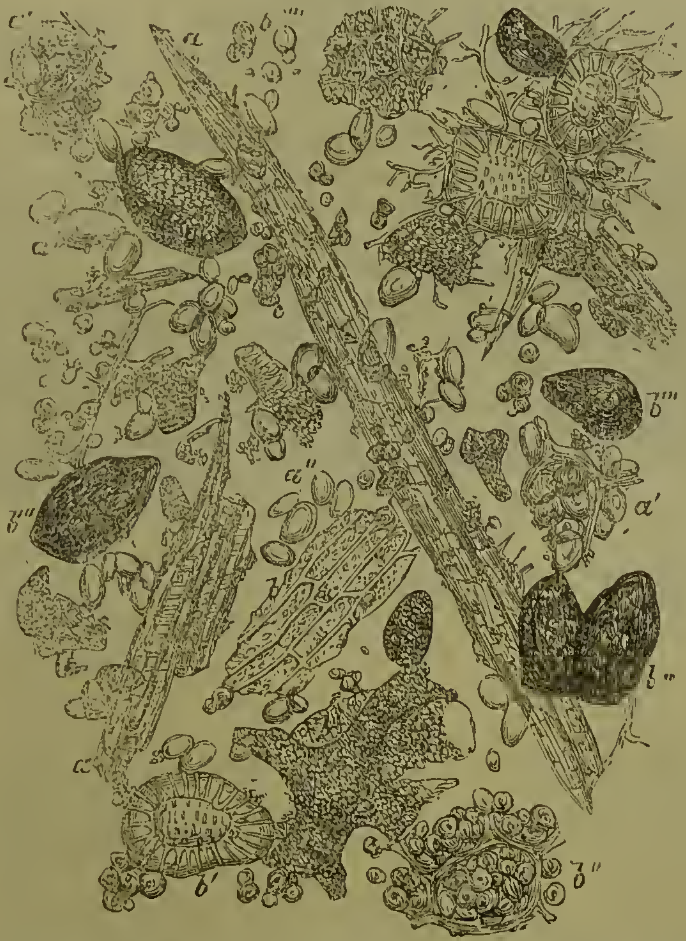
(Magnified 220 diameters.)



a. Fragments of husk. *b.* Stellate cells. *c.* External coat or membrane of seed proper. *d.* Port-wine coloured cells, which form the second membrane of seed. *e.* Cells of the seed, which contain the starch granules. *f.* Loose starch corpuscles.

ground ginger, pimento or allspice, with cassia or cinnamon, and sometimes a small quantity of powdered cloves. Such are the usual ingredients which enter into its composition. In some rare cases, however, it may contain other spices, as mace or nutmeg; but whatever the constituents, and in whatever proportions they are employed, mixed spice, when genuine, should consist entirely of a combination of spices, and should not contain a particle of farinaceous matter other than that proper to the articles composing it. Thus it should never contain *wheat flour*, *potato farina*, or *sago meal*, and whenever any of these are present, the article is to be considered and treated as adulterated.

Fig. 189.
Genuine Mixed Spice.
(Magnified 220 diameters.)



a. Woody fibre of ginger. *a'*. Cells of ginger which contain the starch. *a''*. Starch granules of ginger. *b*. Outer husk of pimento or allspice. *b'*. Stellate cells of same. *b''*. Husk of the seed proper of ditto. *b'''*. Port-wine coloured cells of ditto. *b''''*. Starch cells; and *b'''''*, starch granules of same. *c*. Starch granules and fragments of powdered cinnamon.

The above engraving represents the structure of the several ingredients of which genuine mixed spice is usually formed.

The Adulterations of Mixed Spice.

Of the *twenty-six* samples of mixed spice subjected to microscopic examination, no less than *sixteen*, or considerably more than one-half, were adulterated; and hence it is seen that, of all the spices, mixed spice is the most liable to adulteration.

The substances employed were *wheat flour* in five cases, *ground rice* in two, *sago* in four, *potato flour* in one, and *vegetable substances* undetermined in three of the samples.

The Detection of the Adulterations of Mixed Spice.

The whole of the adulterations of mixed spice are discoverable by means of the microscope: the characters of wheat flour are described and figured at pp. 287 and 289; of rice at pp. 306 and 308; of sago at pp. 375 and 376; and of potato flour at p. 371.

Fuller details respecting the adulteration of spices will be found in the author's work entitled 'Food and its Adulterations.'

The present affords an additional instance of what we have so frequently before observed—namely, that the higher the price of any article, the more it becomes subject to adulteration.

It thus again appears that the public and the revenue are extensively defrauded through the adulteration of the majority of the spices sold.

CHAPTER XXXIV.

CURRY POWDER AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any starch or farina or any vegetable substance added for the sake of bulk and weight only; or added mineral matters, including those employed in the coloration of the Cayenne used.

SEVERAL ingredients enter into the composition of curry powder. The articles of which genuine curry powder of good quality ordinarily consists are turmeric, black pepper, coriander seeds, Cayenne, fenugreek, cardamoms, cumin, ginger, allspice, and cloves. Of these, turmeric forms the largest proportion, next to this in amount are coriander seeds and black pepper; Cayenne, cardamoms, cumin, and fenugreek form but a small portion of the article; while the ginger, cloves, and allspice are in many cases omitted.

The properties and structure of several of the above ingredients have been already fully described and illustrated, as turmeric, black pepper, Cayenne, ginger, cloves, and allspice; it thus only remains to give a description of the other ingredients which enter into the composition of curry powder—namely, coriander seeds, cardamoms, fenugreek, and cumin seeds.

Coriander Seeds.

Coriander (*Coriandrum sativum*) belongs to the natural family Umbelliferæ; it is an annual plant of a foot or a foot and a half in height; it is cultivated in Essex, and although not really indigenous, is frequently met with growing wild in the neighbourhood of Ipswich and some parts of Essex.

Coriander seeds yield about 0·37 per cent. of a volatile oil, which is obtained by distilling the bruised fruit with water. It has an aromatic taste, in its dilute state smelling like orange flowers, but when concentrated having the odour of the seeds. Specific gravity 0·859 (Tromsdorff) or 0·871 at 14° C. (Kawalier). It dissolves in alcohol, ether, and oils, both fixed and volatile, and it explodes violently with iodine. Coriander oil is a mixture of several other oils.

The fruit or seed vessels are globular, about twice the size of white mustard seeds, and of a light-brown colour. Each fruit consists of two hemispherical portions termed *mericarps*, each of which is a seed;

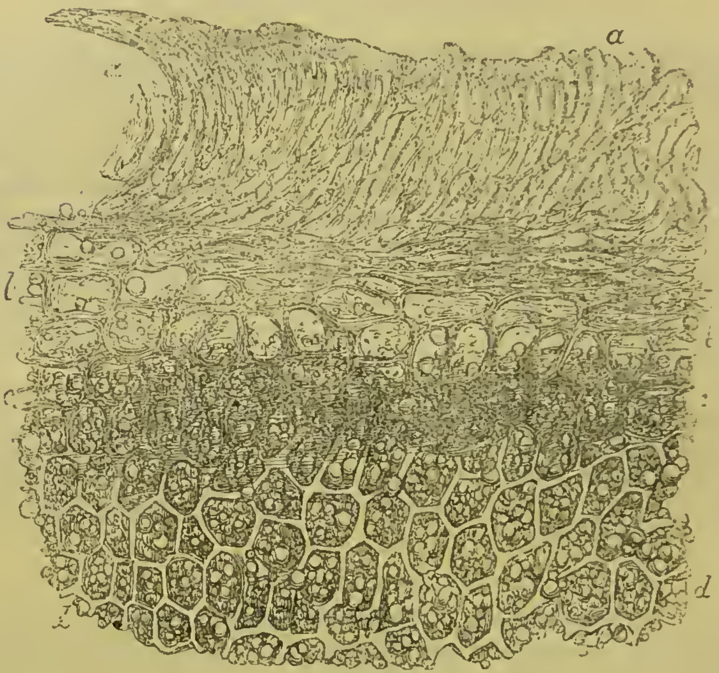
each mericarp exhibits on its outer surface five *primary* ridges, which are depressed and wavy, and four *secondary* ridges, which are more prominent and straight. The channels are without receptacles for the essential oil, or, as they are technically termed, *vittæ*; but near the commissures in each mericarp there is a small vitta, so that each fruit is provided with four of these receptacles.

The epidermis or husk is thick and brittle; when examined with the microscope, it is observed to consist of narrow fibres, which cross each other, and are disposed in a waved manner. It is united to the seed by means of loose cellular tissue, the cavities of the cells being empty. On the removal of the husk, these cells are torn through, some remaining attached to it, and the rest to the surface of the seed. After the separation of the husk, the seed is still of a brown colour. Beneath the cells above described succeeds a delicate fibrous membrane; and next to this is a layer of deeply-coloured cells, which merge into the cells which form the substance of the seed; these are angular, with

Fig. 190.

TRANSVERSE SECTION OF MERICARP OF CORIANDER.

(Magnified 220 diameters.)



a a, fibres forming the husk. *b*, the loose cells which unite the husk to the seed. *c*, the layer of deeply-coloured cells, in contact with the seed. *d d*, cells composing the seed itself.

well-defined parietes, their cavities enclosing oil in a molecular condition. The mature seed does not contain starch (fig. 190).

The peculiar structure of the husk of coriander seeds affords a means by which their presence in curry powder may be readily determined.

Cardamom Seeds, or Grains of Paradise.

The seeds of cardamom yield by distillation a *volatile aromatic oil,* having a very pungent taste. Its specific gravity is 0·945; it is soluble n ether, alcohol, and oils, also in acetic acid and caustic potash. It forms an explosive compound with iodine and it inflames when treated with strong nitric acid. The seeds of *Amomum repens* yield about 4·9 per cent. of this oil. Crystals are deposited from old cardamom oil, having the composition of camphine. Cardamoms likewise contain an *acrid resin* and a fixed *non-drying* oil.

The seed vessels or pods of cardamom are of a triangular form, and consist of three valves, tapering at either extremity to a blunt point; the membrane forming them is thick, tough, and fibrous, and is made up of cellular tissue and bundles of woody fibre, which spread out from the flower-stalk, and are visible on the surface to the naked eye, imparting the striated appearance characteristic of the seed vessel of cardamom.

From its interior, the seed vessel sends off three prolongations or septa, which divide it into as many compartments; each of these contains several hard seeds of a reddish-brown colour and exhibiting upon the surface peculiar markings. The seeds are united together by a gelatinous parenchymatous substance, which, under the microscope, is seen to consist of numerous delicate tubules, filled with granular and oily matter.

The covering of the seed, examined with the microscope, and viewed on its outer surface, is observed to consist of a single layer of coloured cells, much elongated, and of uniform diameter, terminating in rounded extremities, the cells being accurately adapted to each other. Beneath these are other cells, which bear a general resemblance in form to those previously described, but differ in being more irregular, much more delicate, and in the absence of colour; they are disposed in an opposite direction to those of the outer layer (fig. 191, *A*).

In transverse sections, the elongated coloured cells appear as small canals, of a rounded form.

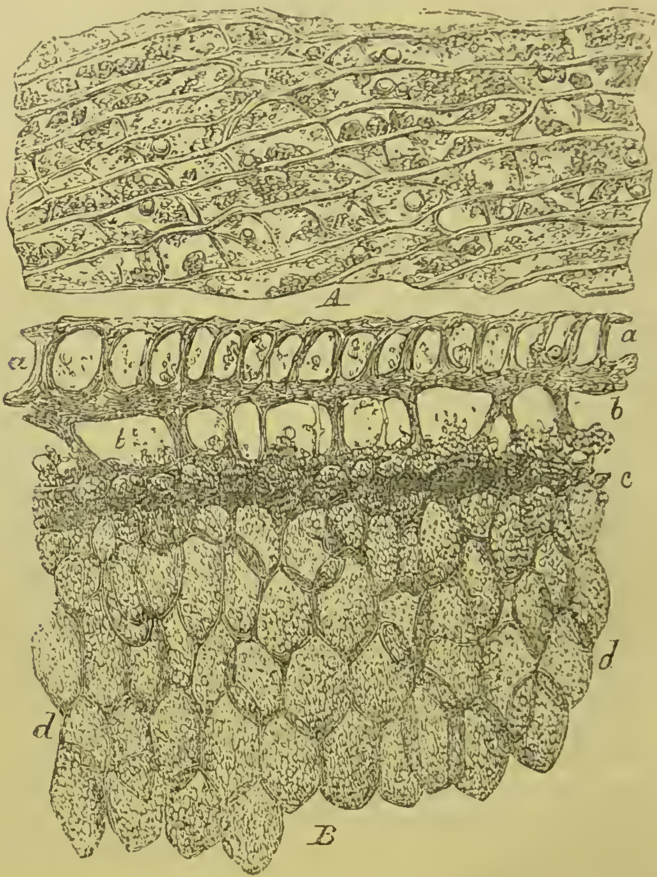
Lying beneath the coating, and forming part of the seed, is a single row of large cells, resembling receptacles. Next in order from without inwards is a layer of small cells, deeply coloured. Next to these succeed the cells which constitute the principal part of the seed; these for the most part resemble closely the cells of pepper, being very angular, but they differ in their more delicate and transparent appearance, and in being minutely dotted (fig. 191, *B*).

Dr. Pereira, in his 'Materia Medica,' quotes the statement made by Schleiden, that he has discovered in the cells of cardamom 'amorphous, paste-like starch.' We find the cells to be completely filled with minute, distinctly-formed starch granules, resembling closely those of rice. Probably the statement of M. Schleiden arose from his having employed but a feeble magnifying power in the examination of the seeds.

Fig. 191.

OUTER MEMBRANE AND TRANSVERSE SECTION OF A CARDAMOM SEED.

(Magnified 220 diameters.)



A. Portion of outer membrane, exhibiting the elongated cells of which it is composed. *B*. Transverse section of seed. *a a*, cells forming outer membrane. *b b*, receptacle-like cells. *c*, layer of coloured cells. *d d*, transparent and minutely-dotted cells, of which the substance of the seed itself is made up, and which are filled with starch corpuscles.

The presence of cardamom seeds in curry powder is most readily determined by means of the dotted and angular cells which form the substance of the seeds.

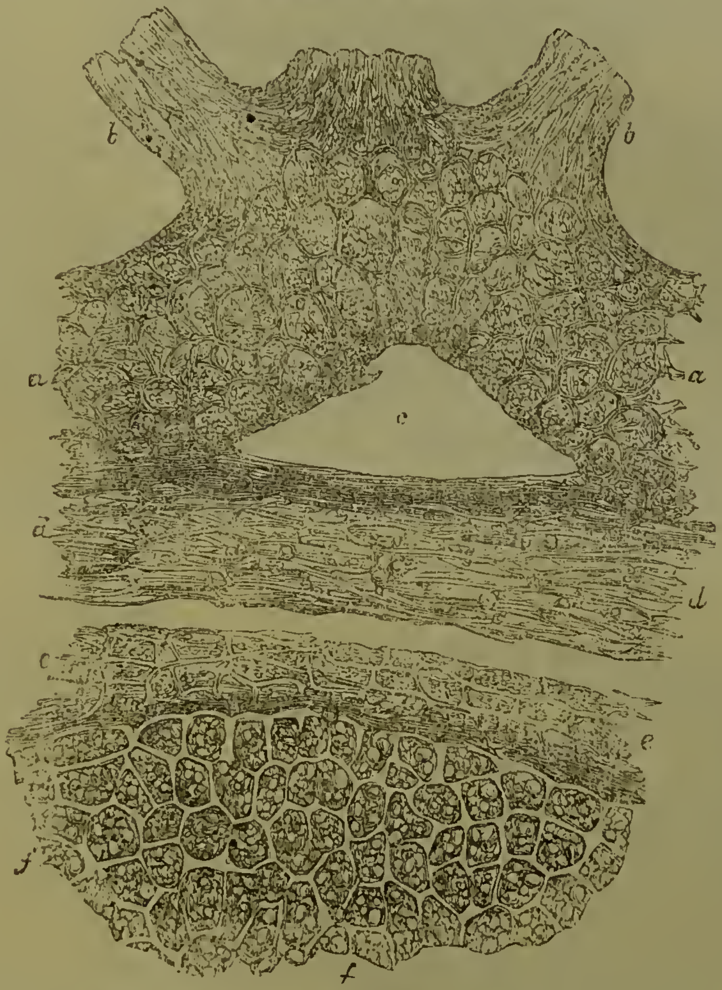
Cumin Seeds.

The cumin plant (*Cuminum cyminum*) belongs, like coriander, to the natural order Umbelliferæ; it is a native of Upper Egypt, but is extensively cultivated in Sicily and Malta. It yields a volatile oil,

Fig. 192.

TRANSVERSE SECTION OF MERICARP OF CUMIN.

(Magnified 220 diameters.)



a a, cells forming the husk. *b b*, commencement of two hairs or prickles. *e*, receptacle or vitta. *d d*, elongated cells which compose the innermost layer of husk. *c c*, cells and fibres of which the external surface of the seed is formed. *f f*, cells of the seed itself, containing oil.

obtained by extraction with absolute alcohol and precipitation by water. It is said to be a mixture of *Cuminol* and *Cymine.*

Cumin seeds resemble somewhat caraway seeds, but they are larger, straighter, and of a lighter colour. The fruit is double, like that of coriander and all other umbelliferous plants, consisting of two seeds or mericarps; each mericarp has five *primary* ridges, which are filiform, and four *secondary* ridges, which are prominent; but both are furnished with very fine hairs or prickles, and under each secondary ridge is a receptacle or vitta.

Transverse sections of a cumin seed exhibit the following structure:—

The hairs or prickles are composed of cells, the long diameters of which are arranged in the long axes of the hairs. The husk or covering of the seed is made up of numerous rounded or angular cells, in the midst of which the large and triangular vittæ are situated: and between the husk and seed itself, there is usually a small space, which is formed by the contraction of the seed after it has arrived at maturity. The surface of the seed is of a pale-brown colour, and its interior whitish and transparent. The exterior portion of the seed is constituted of elongated and flattened cells of a brownish colour, while the interior and chief substance of the seed itself is composed of numerous distinct angular cells, the walls of which are thick and perfectly transparent; their contents consist principally of oil. The seeds do not contain starch (fig. 192).

Cumin seeds possess a very peculiar medicinal taste and smell; and it is to these that curry powder owes the greater part of its characteristic flavour and odour.

Fenugreek Seeds.

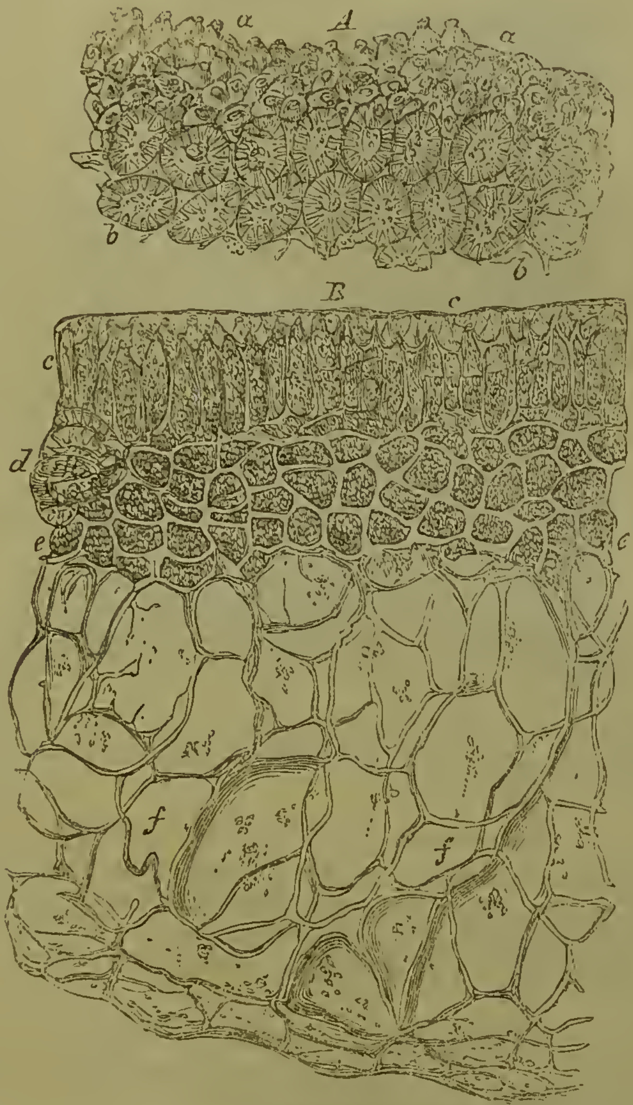
The structure of fenugreek seeds is very characteristic. The husk of the seed consists of three membranes; the outer is formed of a single layer of cells, which bear a remarkable resemblance in shape to a short-necked bottle; the long diameter of these cells is disposed vertically, the narrow, neck-like part being most external, and forming the other surface of the membrane. The second membrane consists of a single layer of cells, two or three times larger than the former, very much flattened, and having their margins regularly and beautifully crenate. The third and innermost membrane is made up of several layers of large transparent cells filled with mucilage; these cells expand greatly when immersed in water (fig. 193).

The seed itself consist of two lobes, which are made up of numerous minute cells; those in the upper part of each lobe are of a rounded or angular form, while those situated near the innermost part become much elongated, the long axes of the cells being placed transversely in each lobe. The entire seed is covered by a single layer of small angular cells (fig. 194).

Fig. 193.

Outer Coat or Testa of a Fenugreek Seed.

(Magnified 220 diameters.)

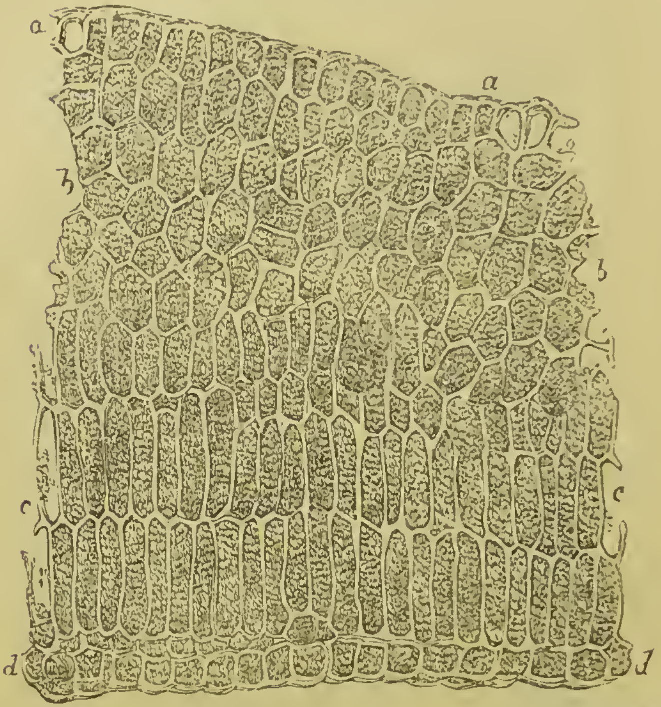


A. Portion of the outer and second membrane stripped off; *a a*, peculiar bottle-like cells; *b b*, crenated cells of second membrane. *B.* Transverse section of husk of seed; *c c*, bottle-like cells; *d*, position of crenated cells; *e e*, layer of coloured cells merging into, *f f*, the large cells which form the innermost membrane, filled with mucilage.

Fig. 194.

Transverse Section of Lobe of Fenugreek Seed.

(Magnified 220 diameters.)



a a, layer of small angular cells on the surface. *b b*, rounded or angular cells. *c c*, the same cells gradually becoming more elongated as they approach the inner part of lobe. *d d*, single row of cells forming the innermost margin of lobe.

THE ADULTERATIONS OF CURRY POWDER.

In various works which we have consulted, we do not meet with a single remark relating to the adulteration of curry powder. Like many of the other articles of which we have treated, this appears to have been neglected by writers on the adulteration of food.

Results of the Examination of Samples.

Twenty-six samples of this article were subjected to analysis; of these *nearly four-fifths were adulterated.*

It appeared—

That *seven* only were *genuine.*
That *nineteen* were *adulterated.*

That *ground rice*, usually in very large quantities, was present in *nine* samples.

That *potato farina* was detected in *one* sample.

That *salt* was present in *eight* of the samples.

That the highly poisonous metallic oxide, RED LEAD, was detected in no less than *eight* of the samples.

That in *seven* of the samples, the adulteration consisted of *ground rice* only.

That in *one* sample, the adulteration consisted of *ground rice* and *salt*.

That in *one* sample, the adulteration consisted of *ground rice* and RED LEAD.

That in *three* samples, the admixture consisted of *salt only*.

That in *three* samples, the adulteration consisted of *salt* and RED LEAD.

That in *three* samples, the adulteration consisted of RED LEAD only.

That in *one* sample, the adulterations consisted of RED LEAD, *potato farina* and *salt*.

The above results do not give the whole of the adulterations to which the samples of curry powder had been subjected, since they do not include the ferruginous earths, which were shown, in our article on 'Cayenne,' to be so frequently employed to impart colour to that substance.

We have thus shown that curry powder was adulterated nearly to the same extent as Cayenne, and with ingredients equally pernicious. Since the quantity of curry powder eaten at a meal is so considerable, its adulteration with red lead is even more prejudicial and dangerous than in the case of Cayenne. Not long since we received a parcel of curry powder from a surgeon, accompanied by the statement that the person who had partaken of it had been made very ill by it. We found it, on analysis, to contain a large quantity of lead.

The lead in curry powder is, no doubt, generally introduced through the adulterated Cayenne employed in its manufacture. It is possible, however, that chromate of lead may here, as in some other cases, be used to intensify and render more permanent the colour of the powder.

The whole of the ingredients required for making curry powder may be obtained of most seedsmen.

With a common pestle and mortar the seeds may be reduced to powder, and thus the housekeeper may herself prepare genuine curry powder, of the best quality, at a cost of about 2*d*. per ounce. Since curry powder is retailed at 6*d*., 8*d*., and even 1*s*. an ounce, it evidently bears an enormous profit. What, then, must be the gain upon the sale of an article which is made up principally of turmeric powder, salt, ground rice, and inferior capsicum berries? and of such a mixture many of the curry powders purchased at the shops almost entirely consist.

The Detection of the Adulterations of Curry Powder.

The adulterations of curry powder, with the exception of potato farina or starch, met with in one sample, being the same as those of Cayenne, the methods for their discovery are also the same; the reader is therefore referred to the article on 'Cayenne.'

The presence of potato starch is detected by means of the microscope; the characters of its granules are described under the head of 'Arrowroot.'

CHAPTER XXXV.

TURMERIC AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any added vegetable or mineral substance.

Turmeric powder consists of the ground tubers of a plant belonging to the same genus as ginger, viz. *Curcuma longa*, and which is extensively cultivated in India and China.

Composition of Turmeric.

The composition of turmeric is shown in the following analysis :—

John's analysis.

Yellow volatile oil	1
Curcumin	10 to 11
Yellow extractive	11 to 12
Gum	14
Woody fibre	57
Water and loss	7 to 5
	100

Vogel and Pelletier's analysis.

Acrid oil.	Starch.
Curcumin.	Woody fibre.
Brown colouring matter.	Chloride of calcium.
Gum (a little).	Turmeric.

To extract curcumin, the pulverised root is boiled with water, the residue treated with boiling alcohol ; the alcoholic solution is filtered, evaporated, the residue digested with ether, and the ethereal solution in its turn evaporated, when the curcumin is obtained, together with a little essential oil.

It is heavier than water, in which it is insoluble, but dissolves readily in alcohol, ether, and in fixed and volatile oils. It melts at 40° C.

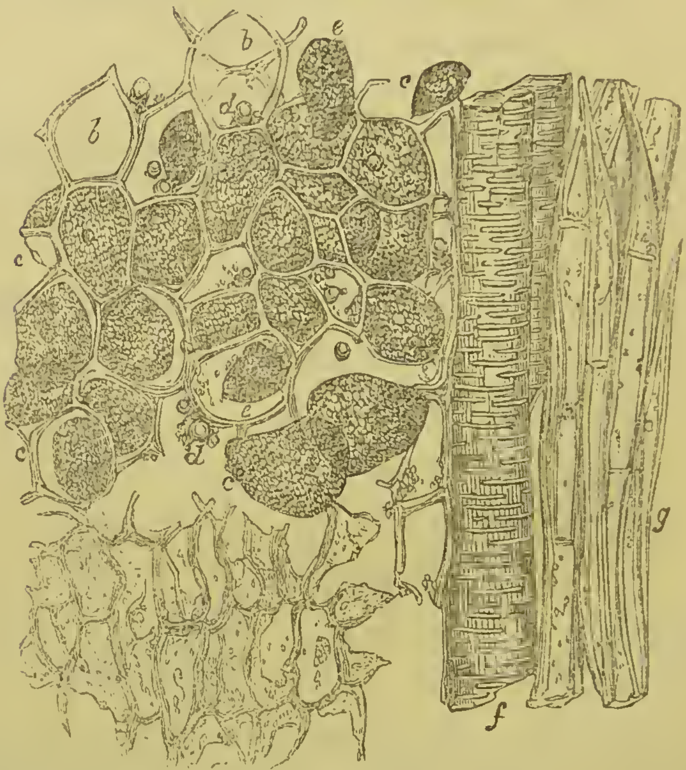
The alcoholic solution of turmeric is characterised by its beautiful green fluorescence ; the spectrum of the solution not exhibiting any peculiar dark or bright bands. The fluorescence is best seen by placing the solution of turmeric in alcohol or benzol in a small beaker and concentrating the rays of the sun in the solution by means of a burning-glass, when the illuminated cone thus produced will appear bright green.

Structure of Turmeric.

The structure of the tuber of turmeric is well exhibited in the annexed figures.

Fig. 195.

SECTION OF TUBER OF TURMERIC.



a a, epidermis; *b b*, transparent cells; *c c*, yellow masses; *d d*, oil globules: *e e*, resinous masses; *f*, dotted duct; *g*, elongated cells of woody fibre, lying by the side of the duct.

Turmeric powder consists of large cells; some of these are loosely imbedded in a reticular tissue, but others, and these the majority, are quite free; they may be recognised with facility, under the microscope, by their size and bright yellow colour (fig. 195).

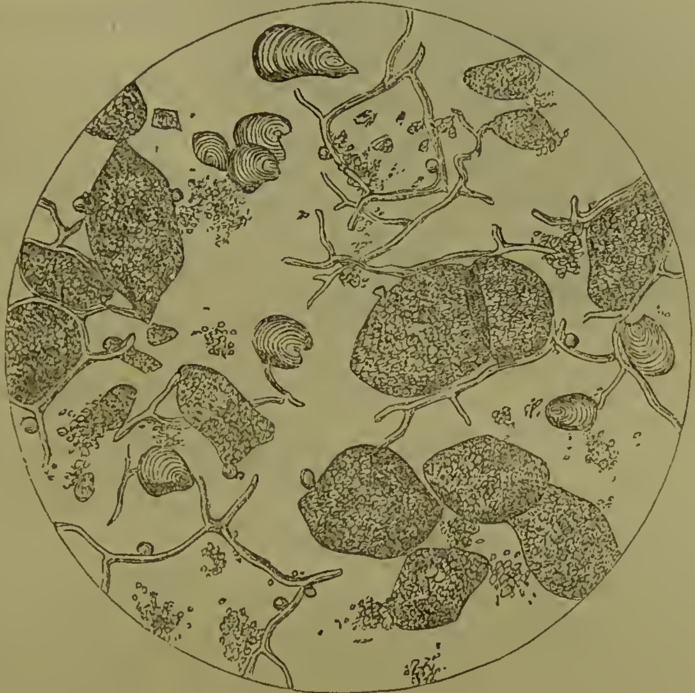
When crushed, each cell is found to contain colouring matter as well as a number of starch granules, resembling closely those of Curcuma arrowroot, already described and figured (fig. 196).

On the application of iodine the cells become of a deep blue, and with potash, of a reddish colour.

THE ADULTERATIONS OF TURMERIC.

Of *fourteen* samples of turmeric powder subjected to examination, two were adulterated with *yellow ochre*, to the extent of nearly 20 per cent., while nearly all the other specimens contained considerable quantities of *alkali*, carbonate of soda or potash, added no doubt to heighten the colour of the powder.

Fig. 196.



This engraving represents the appearance and characters of *genuine ground* TURMERIC. Drawn with the Camera Lucida, and magnified 220 diameters.

Inasmuch as turmeric enters so largely into the composition of curry powder, mustard, and some other condiments, it became necessary to ascertain whether it was liable or not to sophistication.

The Detection of the Adulterations of Turmeric.

Yellow ochre consists of oxide of iron diluted with chalk; the ash of turmeric powder must therefore be tested in the manner already elsewhere directed for the detection of those two substances. The presence of the ochre is in general sufficiently indicated by the colour and weight of the ash.

Should the ash, say, of 10 grammes of the turmeric contain alkali, as carbonate of soda or potash, we must proceed as follows: the alkali must be dissolved out of the ash by means of distilled water. The solution is coloured blue by means of a drop of tincture of litmus, and the amount of alkalinity is ascertained by the addition from a graduated burette of a standard solution of sulphuric acid, the change in the colour of the litmus indicating the end of the reaction.

For the determination and estimation of potash and soda the processes will be found given in the article on 'Tea.'

It is always well to test, before commencing the analysis, the reaction of the watery solution of the ash, as, unless this is decidedly alkaline, it does not contain alkali, and again it is proper also to test the ash, to ascertain whether salt has been used, and which is sometimes employed to heighten the colour of vegetable powders. Very generally the presence of alkali in the ash of turmeric powder is sufficiently indicated by the greenish colour, more or less intense, exhibited by it when first removed from the fire.

CHAPTER XXXVI.

LIQUORICE AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any added substance, vegetable or mineral.

Liquorice is an article largely consumed, and it furnishes an illustration of a system of adulteration which extends to a variety of other drugs and pharmaceutical preparations.

Liquorice is met with under various forms and names; thus, there is *stick liquorice*, the *powder*, the *Pharmacopœial extract*, the *foreign extract*, *pipe liquorice*, and *Pontefract lozenges.*

Stick liquorice consists of the underground stem or rhizome of a plant belonging to the genus *Glycyrrhiza*, usually in this country, *Glycyrrhiza glabra*; the powder is the root ground and pulverised, while the other preparations named consist of the extract; this, in the case of pipe liquorice and Pontefract lozenges, is said to be refined.

The foreign extract, known as Solazzi extract or juice, is considered the best; and, accordingly as it is prepared in Spain or Italy, it is called Spanish or Italian juice. We learn from Pereira that the Spanish extract is prepared in Catalonia from *Glycyrrhiza glabra*, while the Italian extract is obtained in Calabria, from *G. echinata*. Of late years the liquorice plant has been extensively cultivated in this country for medicinal use, especially at Mitcham, where so many different kinds of medicinal plants are grown.

The constituents of the root of *Glycyrrhiza glabra*, according to the analysis of Robiquet, are *liquorice sugar* or *glycyrrhizin*, *starch*, *asparagin*, *resinous oil*, *albumen*, *woody fibre*, and *salts*, especially *phosphate* and *nitrate of lime* and *magnesia*. The quantities of these several constituents are not given by Robiquet, nor does he mention *gum* or *oxalate of lime* as constituents, although these abound in the juice of the root.

As, before entering upon the consideration of the chemical adulteraions of any article, it is necessary that we should be acquainted with the proportions of the principal ingredients of which that article is composed, we instituted in the first place certain analyses of the *root*, the *powder*, and the *extract*.

The following is the composition of 100 parts of the *fresh root*:—

The Fresh Root.

Glycyrrhizin	8·60
Gum	26·60
Matter soluble in alcohol, chiefly resin	·75
Albumen	·97
Starch	22·91
Woody fibre	13·36
Moisture	26·81
Ash, 3·07 per cent.	
Total	100·00

The analysis of 100 parts of the *undecorticated powder* furnished the following results :—

The Powder.

Glycyrrhizin	10·40
Gum	43·30
Matter soluble in alcohol, chiefly resin	1·09
Albumen	1·50
Starch	24·41
Woody fibre	15·20
Moisture	4·10
Total	100·00

The analysis of the *decorticated powder* furnished nearly similar results :—

The Decorticated Powder.

Glycyrrhizin	13·00
Gum	37·10
Resin	·80
Albumen	1·80
Starch	29·52
Woody fibre	16·58
Moisture	1·20
	100·00

Five hundred parts of the fresh root furnished 175 parts of extract; while the same quantity of the powder of the dried root gave 275 parts of extract. Lastly, 100 parts of this extract, dried at a temperature of 100° C., yielded 19·3 parts of liquorice sugar, and 80·3 parts of matter insoluble in alcohol, and which consisted chiefly of gum with a little albumen.

When pure and genuine, extract of liquorice is entirely soluble in water.

As will be shortly apparent, the above analyses furnish some useful data, by which the quality of the different kinds of liquorice may be judged of.

Glycyrrhizin may be thus obtained. The filtered and concentrated aqueous infusion of the root is treated with dilute sulphuric acid. This occasions a dark brown precipitate, which is washed with water until it is quite free from sulphuric acid. It is then dissolved repeatedly in alcohol of specific gravity 0·844. Small quantities of ether are now added to the not too concentrated solution as long as a dark-coloured resinous substance is precipitated. The filtrate on evaporation deposits the glycyrrhizin.

It is a yellow, amorphous, non-fermentable substance, possessing a sweet taste; sparingly soluble in cold, but easily soluble in hot water, soluble in cold alcohol and in warm ether. It is also soluble in alkalies, and is precipitated from these solutions by acids, in an excess of which it is, however, partially dissolved.

By boiling with dilute sulphuric and other acids it is decomposed, *glycyrrhetin* and *glucose* being formed.

Its solution is precipitated by chloride of barium, sulphate of magnesia, sulphate of copper, and basic acetate of lead.

Asparagin may be obtained from liquorice root as follows:—The root, after being cut into pieces, is exhausted with water. The solution is boiled, mixed with acetic acid to separate the glycyrrhizin, and then with acetate of lead, malate and phosphate of lead being thrown down, together with colouring matter. The excess of lead is removed by sulphuretted hydrogen, the filtered liquid evaporated to a small bulk, when, after a few days, crystals of asparagin will become deposited.

STRUCTURE OF LIQUORICE.

The *general structure* of liquorice root is very distinctive; the elements of which it consists are bundles of *woody fibre*, *cellular tissue*, *dotted ducts* or *vessels*, and *starch corpuscles*. These elements are thus arranged:—

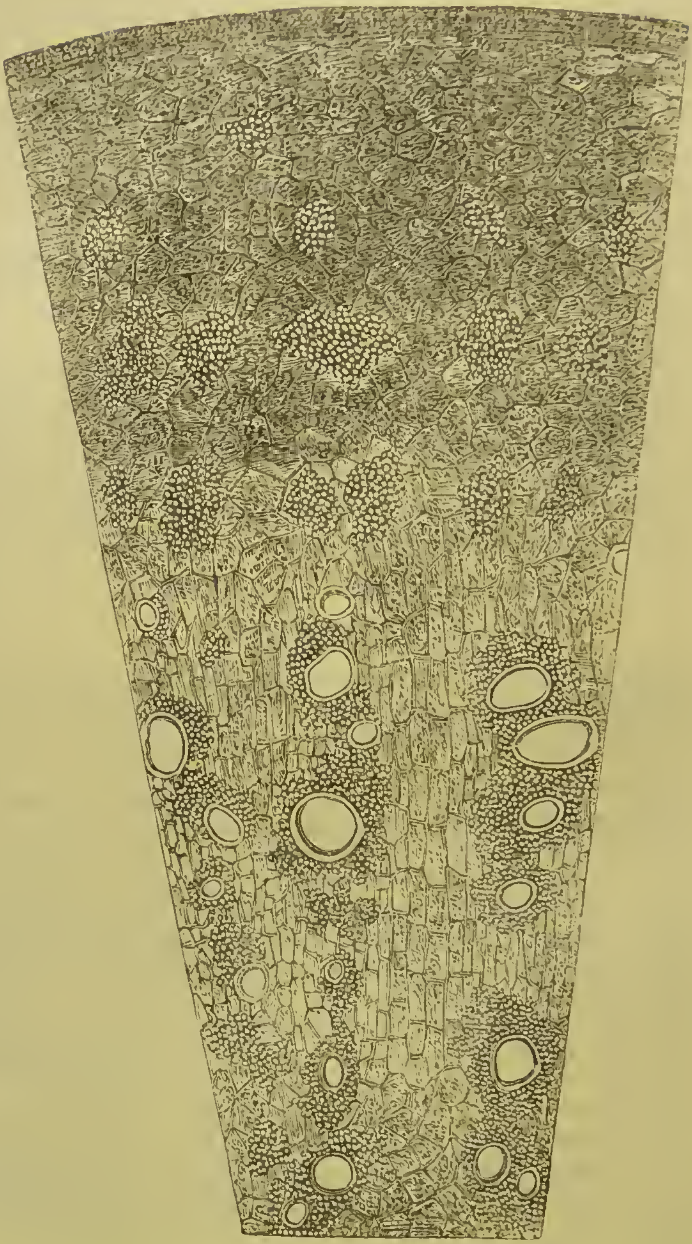
In transverse sections of the root, a linear zone is observed, usually distant from the circumference about the third of the thickness of the root. The part of the root *without* the zone is traversed by bundles of woody fibre, united together by cellular tissue; that *within* the zone is traversed by numerous dotted ducts or vessels as well as by bundles of woody fibre; while the cells of the cellular tissue, which forms the basis of the root, are filled with starch corpuscles (figs. 197, 198 and 199).

These *starch corpuscles* are very characteristic; they are oval and small, and in many of them the central cavity of an elongated form is visible (fig. 199).

The *woody fibre* does not present anything remarkable in its structure; the central cavity is well marked. In sections of the older roots medullary rays may be seen. The several structural peculiarities of liquorice root are all clearly exhibited in the drawings above referred to.

The yellow colouring matter of the root is situated almost entirely in the bundles of woody fibre, and in the walls of the dotted ducts.

Fig. 197.

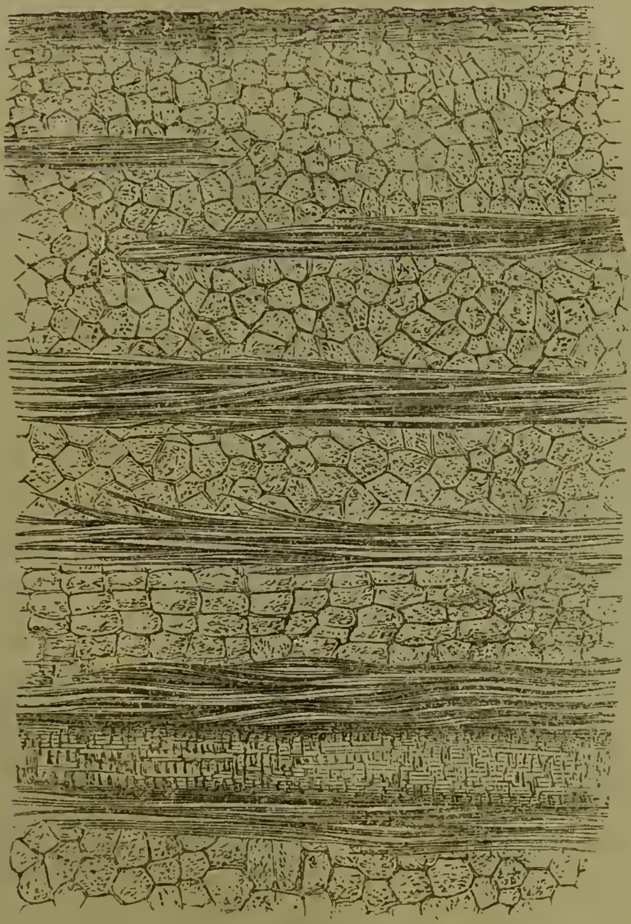


Transverse section of root of LIQUORICE, showing the *dotted ducts*, the bundles of *woody fibre*, and the connecting *cellular tissue*. Magnified 40 diameters.

THE ADULTERATIONS OF LIQUORICE.

Having thus described the chemical composition and the structure of liquorice root, the subject of the *adulteration* of liquorice may next be considered.

Fig. 198.

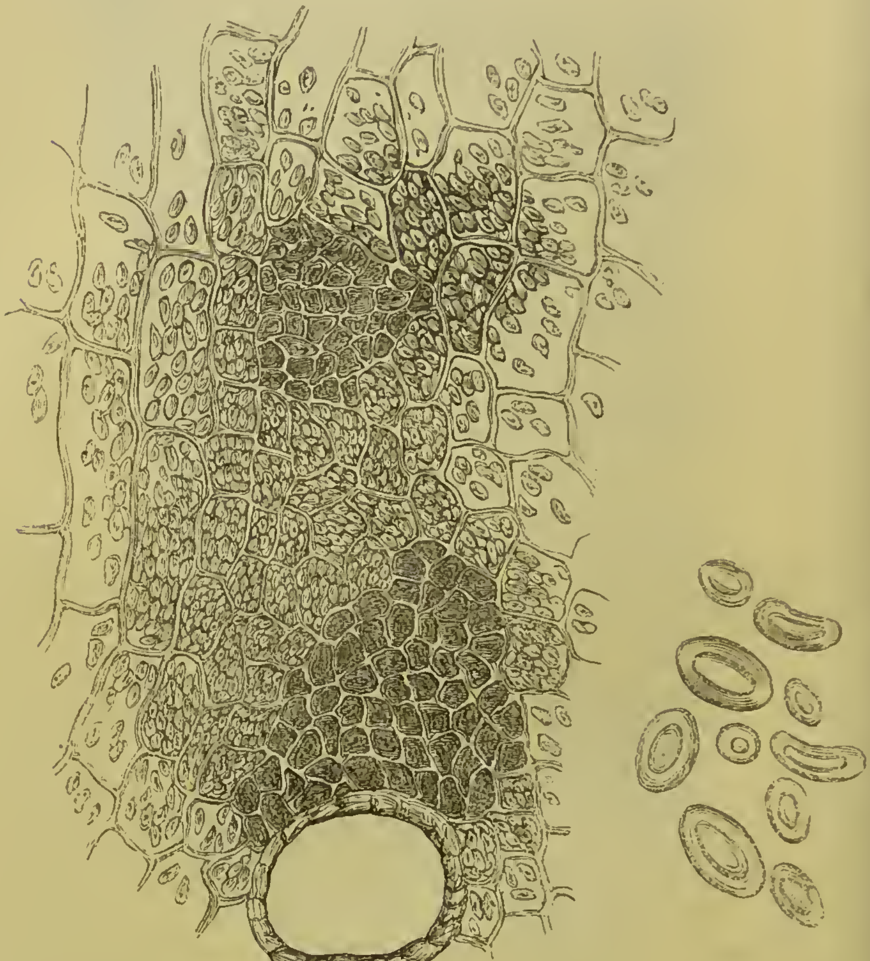


Longitudinal section of LIQUORICE ROOT. Magnified 40 diameters.

On consulting the works of different writers on adulteration, we have met with the following observations relating to liquorice:—

Accum states that Spanish liquorice 'is frequently nothing else than a mixture of the worst kind of *gum arabic*, called *Indian* or *Barbary gum*, imported chiefly for making shoe blacking. A solution of the genuine Spanish liquorice juice is mixed with a solution of Barbary gum; and the mixture, after being inspissated to a proper consistence, is again made up into cylindrical rolls, which, whilst still moist, are covered with bay leaves, and repacked in chests to resemble in every respect the genuine Spanish liquorice juice imported from Catalonia.'

Fig. 199.



Transverse section of LIQUORICE ROOT, magnified 220 diameters, exhibiting *dotted ducts*, two bundles of *woody fibre*, the *cellular tissue*, and the *starch corpuscles*. The loose starch grains are magnified 400 diameters.

Brande, in his 'Dictionary of Materia Medica and Pharmacy,' published in 1836, remarks as follows :—

'The chief consumption of liquorice is in the preparation of the extract, which is imported from the South of Europe under the name of Spanish juice; it is usually burned and otherwise carelessly prepared and adulterated, and often contains *copper*, derived from the pans in which the decoction of the root is evaporated.'

M. Chevalier states that 'liquorice is often falsified by *starch* and a large proportion of inert powders. It has also been falsified by an extract which gives it the taste of hay.

'It contains likewise metallic copper, removed mechanically from the pans of that metal in which it is prepared. But it does not contain salts of copper, a conclusion which results from many experiments made by M. Villain.'

'Liquorice,' writes Pereira, 'as met with in commerce, however, is rarely pure. It contains the soluble principles of the root with some copper scraped off the boiler by the spatula employed to stir the extract during its preparation. Fée says that four ounces of this extract yield two drachms and a half of metallic copper; but there must be some great mistake in this statement. If the foreign extract be dissolved in water, and the solution filtered and inspissated, we obtain *refined liquorice*. But I am informed that the *pipe refined liquorice* is a very adulterated article. The *Pontefract lozenges* are made of refined liquorice, and are much esteemed.'

Results of the Examination of Samples.

We will now proceed to state the results of our own examinations and analyses of liquorice, premising that genuine extract of liquorice should dissolve in water without leaving any residue, and therefore ought not to contain starch; that it should yield from about 90 to nearly 100 parts of extractive matter, according to the state of dryness in which it may happen to be at the time of analysis; this extractive matter should furnish from 75 to 85 per cent. of matter insoluble in alcohol, chiefly gum; and from 10 to 15 per cent. of saccharine matter or liquorice sugar.

The analyses of *thirty-four* samples of liquorice, including the different varieties of *roll* and *pipe* liquorice, and *Pontefract lozenges*, carefully considered, furnish some important results.

Thus it appears that the *gum* of the different kinds of roll liquorice varied from 65·5 to 33·5 grains per cent.; of the *saccharine matter* from 14·9 to 8·9 per cent., part of this in some cases consisting of *cane sugar*; of the *extractive* from 75·9 to 47·1 per cent.

Of the pipe *liquorice*, that the *gum* varied from 22·7 to 45·9 per cent.; the *sugar* from 19·6 to 11·0, the greater part of this consisting of *cane sugar*; and the *extractive* from 57·1 to 43·7 per cent.

Of the Pontefract lozenges the *gum* ranged from 31·5 to 25·7; the *sugar*, partly *cane sugar*, from 18·1 to 13·1; and the *extractive* from 45·9 to 43·8 per cent.

It further appears from the analyses that the whole of the *roll* liquorice furnished insoluble residues, varying in amount from 18·50 to 42·00 per cent. In *twelve* cases these residues consisted of *boiled starch*, probably *rice* (the starch present in the different samples of Solazzi and Baracco extract was always of this kind); in seven samples of *wheat flour*, in one of *potato starch*, and in one of *wheat flour* and *rice*.

That the *pipe liquorices* likewise furnished insoluble residues, for the most part, in still larger amounts than the roll liquorice; thus the smallest residue weighed, after being dried on a water-bath, 34·5 and the largest 41·0 per cent. In five cases this consisted of *wheat flour*, in one of *rye flour*, and in one of *potato, rice, and wheat flours*. In five cases a small part of this residue consisted of *gelatin*, the pipes being furnished with a distinct tube of that substance.

Lastly, that the *Pontefract lozenges* furnished residues consisting of *wheat flour* (subject to the action of heat), which varied in amount from 36·5 to 39·0 per cent.

The *ash* of the different samples of roll and pipe liquorice and Pontefract lozenges varied from 2·50 to 16 per cent., and consisted in several cases of foreign mineral matter; this in one instance amounted to 13 per cent., and was composed of *carbonate of lime*, or *chalk*. The ashes of the pipe liquorices in two or three cases were so deeply coloured as to lead to the suspicion that some coloured mineral earthy substance had been employed to increase their weight.

It is thus evident that the different kinds of roll, pipe liquorice, and Pontefract lozenges are subject to very extensive adulteration, this in some instances amounting to nearly one-half the article.

As a rule, the pipe liquorice and Pontefract lozenges contain a larger amount of foreign starchy matter than even the inferior descriptions of roll liquorice. Many of the pipe liquorices are in addition furnished with a thick coating of gelatin; this is sometimes of the worst quality and but little superior to glue. The best way to exhibit the tube of gelatin encasing the pipes is to place them in cold water; the pipes will swell up and increase to two or three times their original size; when in this state, the gelatin may be easily removed.

The ingredients employed in the adulteration of the descriptions of liquorice above referred to consist, then, of starch of various kinds, as *wheat, barley, rye, rice flours*, and *potato starch*, either separately or in combination; *cane sugar, gelatin*, and foreign *mineral matter*, as *carbonate of lime*.

Although not immediately connected with the object of this article, we yet, when engaged in the analysis of liquorices, thought it desirable to determine how frequently and to what extent the samples were contaminated with *copper*. We detected that metal in thirteen of the twenty-one roll liquorices examined, in greater or lesser amount: the quantities in three of the samples were, for the 100 parts, ·8, ·25, ·30 of a grain. Traces of copper were found in only one of the pipe liquorices, and in none of the Pontefract lozenges.

We will now pass on to state the results of the examination of the *extract* of liquorice of the *Pharmacopœia*.

Ten samples of extract of liquorice were examined; four of these dissolved nearly without residue, and were genuine; the remainder of the samples deposited insoluble residues amounting to 3, 13, 17, 9, 7, 18·5 and 33 per cent. respectively. In four cases they consisted of *boiled starchy matter*, and in one instance of *starchy matter* and *gelatin*.

The sample containing the gelatin furnished only 65·5 per cent. of extract, and the insoluble residue amounted to 17 per cent., thus leaving 18 per cent. for moisture, which large quantity the liquorice was partly enabled to retain, in consequence of its admixture with gelatin.

It is evident from the nature and quantities of the insoluble residues that the adulterated samples of extract of liquorice consisted of the *foreign* extract melted down.

The compilers of the Pharmacopœia were doubtless led to prescribe a form for the preparation of a genuine extract of liquorice by the knowledge of the fact of the adulteration of the foreign extract. We thus perceive to what an extent the regulations of the Pharmacopœia are evaded in this case. In further illustration of the extent to which the Pharmacopœia in this and doubtless in many other articles is disregarded, we may mention that we were only able to procure the Pharmacopœial extract at about one-third of the chemists' shops at which we enquired for it. In one case, although we particularly requested to be furnished with the true extract, some of the foreign extract was coarsely powdered while we waited, and handed to us as the article we enquired for, and for which we were made to pay twice the usual price.

In the next and last place, we will proceed to state the results of the examination of numerous samples of *powdered liquorice*.

Of *twenty-eight samples* of liquorice in *powder* subjected to examination, *eleven were adulterated*. Of these *one* consisted chiefly of *wheat flour*, *another* contained a large quantity of *woody fibre*, *two* contained much foreign *woody fibre*, two *woody fibre* and *turmeric*, another *woody fibre* and *wheat flour*, *one* was made up chiefly of *Indian corn*, *potato* and *sago flours*, and *turmeric*, *another* of *sago*, *woody fibre*, and *much turmeric*, *another* of *East Indian arrowroot* and a little *turmeric*, and *another* consisted almost entirely of *potato flour*, a little *wheat flour*, and *turmeric*. Some of the samples likewise contained *cane sugar*.

We stated at the commencement of this paper we believed it would be found that liquorice afforded an example of a system of adulteration which extended to other and more important articles of the Materia Medica. We will now adduce some evidence to show that this is really the case.

It has been ascertained that some wholesale druggists prepare, and they nearly all keep, what are known in the trade as *compound powders*. One of these is liquorice, the genuine powder being distinguished as Pulvis Glycyrrhizæ Verus.

Other compound powders are those of turmeric, gentian, fenugreek, aniseed, cumin, and elecampane.

Those of turmeric, gentian, and fenugreek are usually prepared after the following receipts, or some modifications of them:—

Turmeric Powder.

Yellow ochre . .	1 lb.
Turmeric . . .	1 lb.
Wheat flour . .	2 lbs.

Gentian Powder.

Gentian . .	1 lb.
Linseed . .	1 lb.
Wheat flour .	2 lbs.
Cape aloes .	grs.

Fenugreek Powder.

Fenugreek, lb. iss.
Turmeric, ℥ xii.
Wheat flour, lb. iii.

This custom is defended on the plea that no deception is practised, and that these powders are sold as compound articles. This may be so as between the wholesale and retail dealers in drugs, but it assuredly is not the case as between these parties and the medical profession and the public; the liquorice powders, the extensive and varied adulteration of which we have just described, were sold simply as liquorice, and no acknowledgment whatever was made even in a single instance of their compound character.

It is evident that the practice of making and selling these compound powders is most objectionable; it indicates a laxity of principle, both on the part of the wholesale and retail dealers in drugs, and it is clear that the medical profession and the public are by it seriously imposed upon.

It is affirmed that it is as cattle medicines that these compounds are used. Although this is the case to some extent, yet it is very certain that they are not thus exclusively employed; besides, why should these adulterated powders be thrust down the throats of cattle?

We have now shown that liquorice in all its forms and varieties is subject to an enormous amount of adulteration, and that various substances are employed for that purpose.

Thus it has been shown—

That the whole of the foreign extracts or roll liquorices were adulterated, some to the extent of nearly 50 per cent.

That the whole of the pipe liquorices examined were also adulterated, some of them not containing one-third their weight of liquorice.

That the Pontefract lozenges likewise contained but little liquorice.

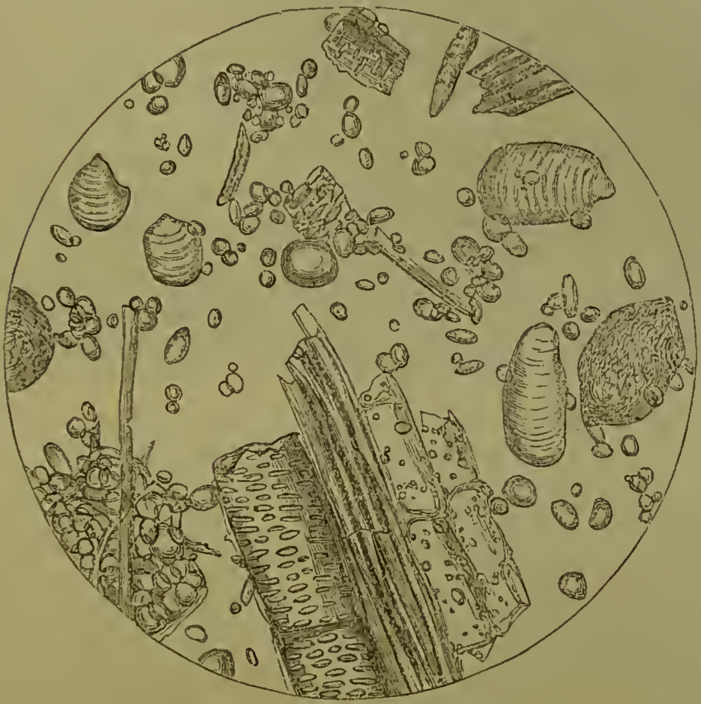
That of the samples of the extract of liquorice of the Pharmacopœia, one-half were adulterated; these for the most part consisting of the foreign extract melted down.

Lastly, that a large proportion of the powdered liquorices examined were adulterated, many of them containing only as much liquorice as was necessary to impart the flavour of the genuine powder.

Of the adulterations discovered in roll liquorice, some are practised by the foreign preparers of the extract, while others are the work of parties nearer home. It is, we believe, not uncommon for the foreign extract to be melted down after its arrival in this country, for the purpose of subjecting it to further adulteration. In some cases the adulterating ingredients, as flour and chalk, are so clumsily mixed with the liquorice, that particles and masses of these substances may be detected by the naked eye alone, and may be picked out with a penknife.

The adulterations of pipe and powdered liquorice described were no doubt effected in this country.

Fig. 200.



LIQUORICE POWDER, adulterated with *Turmeric* and *East Indian arrowroot*. (Magnified 220 diameters.)

Of the ingredients employed in the adulteration of liquorice, some are themselves liable to adulteration. This is the case with the turmeric used, which we have found to be adulterated to the extent of nearly 20 per cent. with *yellow ochre*.

THE DETECTION OF THE ADULTERATIONS OF LIQUORICE.

Since most of the adulterations of liquorice consist in the addition of vegetable substances of different kinds, the microscope affords the chief means for their discovery.

The characters of *wheat flour*, *turmeric* and *East Indian arrowroot* have already been described and delineated in woodcuts; the appearances presented by liquorice powder adulterated with the two last named substances are also exhibited in fig. 200.

The chief chemical adulterations practised are those with *sugar* and *chalk*. The process for the detection and estimation of the last is pointed out under the head of 'Tea,' while for the detection of *cane sugar* in liquorice powder we may proceed as follows:—

Add about 50 cc. of cold water to 15 grammes of the powder; filter, and evaporate on a water-bath at a gentle heat. If cane sugar be present it will crystallise as the evaporation draws near to an end, and if now a little sulphuric acid be added, the residual mass will immediately become charred. Sulphuric acid does not carbonise liquorice sugar or glycyrrhizin, but forms with it a chemical compound or sulphate.

Glycyrrhizin and cane sugar may be thus separated from each other: add excess of basic acetate of lead to a strong filtered infusion of the powder, remove the lead held in solution by means of sulphuretted hydrogen, filter, evaporate on a water-bath, and when dry weigh the residue, which consists of cane sugar.

Or the glycyrrhizin may be removed from the powder or the extract by means of warm ether. The residue, containing the cane sugar, may be converted into glucose by boiling with dilute sulphuric acid, and the glucose estimated by means of the copper test.

CHAPTER XXXVII.

ANNATTO AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

In cake and roll annatto, any foreign vegetable or mineral substance, and in solutions, any foreign vegetable or mineral substance other than the alkali necessary to the solution of the annatto.

The next article which falls under our consideration is annatto; this, though not employed as food, is yet added to several articles of consumption, and it therefore becomes of interest to ascertain whether it is subject to adulteration or not.

Annatto is the colouring matter obtained from the seeds of a plant named *Bixa orellana*, L., and which forms the type of the small natural order *Bixineæ.* It is a native of South America, the West and East Indies; but the article annatto is chiefly prepared in Brazil and Cayenne.

The tree is an evergreen, and the seeds are enclosed in pods, the colouring matter being situated on the outside of the seeds.

It appears that two different processes are pursued in order to separate the colouring matter. According to the ordinary process, the seeds, after being removed from the pods, are bruised and transferred to a vat, when they are mixed with as much water as covers them. Here they are left for several weeks or months. 'The substance thus obtained,' Dr. Ure states, 'is now squeezed through sieves, placed above the steeper, that the water containing the colouring matter in suspension may return into the vat.

'The residuum is preserved under the leaves of the Annana (pineapple tree) till it becomes hot by fermentation. It is then again subjected to the same operation, and this treatment is continued until no more colour remains.

'The substance thus extracted is passed through sieves, in order to separate the remainder of the seeds; and the colour is allowed to subside. The precipitate is boiled in coppers until it is reduced to a consistent paste. It is then suffered to cool, and is dried in the shade.'

The second process is that recommended by Leblond. He proposes simply to wash the seeds until they are entirely deprived of colour, to precipitate the colouring matter by means of vinegar or lemon juice, and to boil it up in the ordinary manner, or to drain it in bags, as is practised with indigo. The annatto prepared in this way is said to be four times as valuable as that made according to the first-described process.

It does not appear from either of these descriptions that anything is added to the annatto except water. This is important with reference to its adulteration.

Before proceeding to enter upon the question of the adulteration of any article, the first step necessary is to make oneself acquainted with its properties and characteristics; and if the substance be vegetable, it is requisite that we should determine its structure by means of the microscope. We thus obtain certain fixed data or standards of comparison from which to start.

STRUCTURE OF THE SEED OF ANNATTO.

Subjecting the seeds of annatto to examination with the microscope, we find that their outer or red portion does not exhibit any very definite structure, that the surface of the seed proper consists of narrow or elongated cells or fibres, vertically disposed; while the inner white portion consists of cells filled with numerous starch corpuscles, well defined, of medium size, and resembling in form and in the elongated and stellate hilum the starch granules of the pea and bean (fig. 201).

In *genuine* manufactured annatto but little structure is met with; in portions of the outer cells are however seen—as well as in those specimens which in the course of their preparation have not been subjected, as they usually are, to the action of boiling water—a few of the starch corpuscles.

Annatto is used by dyers, painters, soap-makers, and to colour milk, butter, and cheese.

By dyers and soap-makers it is frequently purchased for use in the state in which it is imported, these parties adding the alkali as a solvent as they use it; in these cases it does not pass through the hands of the English so-called manufacturers at all. In other cases the manufacturers re-prepare it in the several forms of roll, cake, orange, black, and fluid annattos.

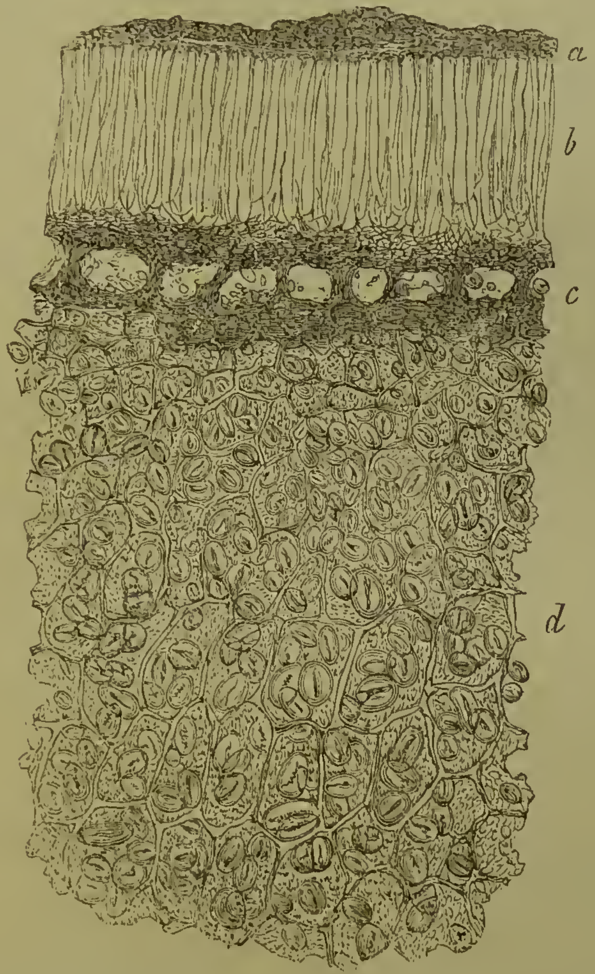
COMPOSITION OF ANNATTO.

The pulp surrounding the unfermented fresh seeds was found by Dr. John to consist of 28 parts of colouring resinous matter, 26·5 of vegetable gluten, 20 of ligneous fibre, 20 of colouring, 4 of extractive matter formed of matters analogous to vegetable gluten and extractive, and a trace of spicy and acid matters.

The colouring matter is soluble in water, but more so in alcohol and alkalies. The latter change its colour somewhat from red to orange. When annatto is used as a dye, it is cut in pieces and boiled in a copper with crude pearl ashes.

On subjecting the seeds of annatto to examination, we obtained an ash which weighed 4·80 per cent., and which was nearly white, with here and there a faint tinge indicating the presence of a mere trace of iron; it yielded ·20 per cent. of alumina, tinged only very slightly with iron.

Fig. 201.



Section of seed of ANNATTO. *a*, *coloured portion*; *b*, cells of *husk*; *c*, layers of cells situated between the husk and seed proper; *d*, cells of *seed* proper containing *starch corpuscles*.

The red or outer part of the seeds yielded on examination nearly similar results.

These results may therefore, as we shall see more fully hereafter, be taken as representing to some extent the proper weight of the ash of genuine annatto, and of the iron and alumina which it usually contains.

THE ADULTERATIONS OF ANNATTO.

There is scarcely an article with which we are acquainted subjected to so large an amount of adulteration, and this of the grossest possible description, as annatto.

The substances employed are various, some of them being organic and others inorganic.

The *organic* adulterations which we ourselves have detected are those with *turmeric, rye, barley*, and *wheat* flours.

The *inorganic* adulterations observed by us are as follow: with *sulphate of lime, carbonate of lime, salt, alkali, an oily substance*, probably soap, red ferruginous earths, mostly *Venetian red, red lead*, and *copper*.

The employment of large quantities of flour and of lime so reduces the colour of the annatto that it becomes necessary to have recourse to salt, alkalies, and the red earths, to restore it to something approaching its natural standard.

The effect of salt in heightening the intensity of vegetable reds is well known, and hence its use.

The lead detected was probably introduced into the annatto through the Venetian red used.

At first we were disposed to regard the copper in annatto as an accidental impurity; there is good reason for believing that it is purposely added to prevent the annatto from becoming attacked with fungi, and to which it is so prone, in consequence especially of its admixture with such large quantities of flour and salt. The salt, by attracting moisture, hastens the decomposition of the flour.

Results of the Examination of Samples.

The following results were obtained from the examination of *thirty-four* samples of *annatto* of all kinds *as imported*, as obtained from *English manufacturers*, and as purchased from *dealers*:—

1. That of the thirty-four samples of annatto of all kinds examined, *two only were genuine*, and were entirely free from adulteration; these being two red cake annattos as imported.
2. That the whole of the remaining samples consisted of *mixtures in various proportions of one or more substances, these amounting in many cases to one-half, and in some instances to even two-thirds of the entire specimens.*
3. That of the two samples of *black annatto*, obtained from manufacturers, one furnished a highly ferruginous *ash*, which was very alkaline, and amounted to 32·50 per cent., and which consisted of an *alkali*, some *chalk*, and *a red ferruginous earth*; while the

second yielded an *ash* that weighed 35·36 per cent., which was still more ferruginous, and consisted of *alkali* and *some red earth.*

4. That of the four samples of *orange cake annatto,* obtained from manufacturers, one furnished an *ash* which amounted to 62·00 per cent., and which consisted chiefly of *chalk,* with a trace of *lead*; the *ash* of the second sample weighed 57·72 per cent., and also consisted principally of *chalk*; the third sample contained a large quantity of *turmeric* and a little *wheat flour*; the *ash* amounted to 44·4 per cent., and consisted of *chalk* and some *red earth*; while the *ash* of the fourth sample weighed 63·00 per cent., and was composed chiefly of *chalk.*
5. That of the two samples of *red cake annatto,* procured from manufacturers, one contained a very large quantity of *wheat flour,* and yielded 17·12 per cent. of *ash,* which consisted of *salt* and some *red earth*; the other also contained a very large quantity of *wheat flour,* and furnished 14·26 per cent. of *ash,* consisting chiefly of *salt* and some *ferruginous earthy colouring matter.*
6. That of the five samples of *orange cake annattos,* purchased of different retail dealers, one yielded 57·80 per cent. of *ash,* which consisted principally of *chalk*; a second contained a very large quantity of *turmeric,* and gave an *ash* which weighed 36·56 per cent., and which was composed of *chalk* and a *red ferruginous earth*; the third contained the starch of *sago,* the *ash* weighing 58·46 per cent., which was composed chiefly of *chalk*; the fourth contained a very large quantity of *turmeric,* and yielded 40·30 per cent. of *ash,* composed of *chalk, ferruginous earth,* and a little *salt*; while the fifth gave 59·12 per cent. of *ash,* which consisted principally of *chalk* with traces of *lead.*
7. That the samples of *red roll annatto* nearly all contained large quantities of either *wheat, barley,* or *rye flour*—usually the latter, to the extent of 30 and even over 40 per cent.; much *salt* and some *red ferruginous earth,* as *Venetian red, red ochre,* or *reddle.*

Reviewing then the results of the microscopical and chemical examination of the *Thirty-four* samples of annatto, it appears that large quantities of *turmeric* were present in three samples; *wheat* or *barley flour* in four, and *rye flour* in nine, the majority of these samples containing full forty per cent. of flour; that *chalk* was present in a great many cases, frequently to the extent of fifty and even over sixty per cent., *sulphate of lime* in at least five cases, a *red ferruginous earth* in a great many, an *alkali* in several, *salt* in many, *lead* in five cases, and *copper* in at least four samples.

The *iron* and *alumina* amounted in some cases to near three and even over five per cent. Had all the samples been examined quantitatively for iron, it is probable that still larger amounts would have been met with, as the worst cases were not specially selected for examination.

In two of the five samples in which *lead* was detected, the quantity was not weighed, and is described as *traces* only, while in the other three samples the quantities amounted to ·30, ·50, and to 1·20 per cent.

Mr. Hogg, the author of the 'Treatise on the Microscope,' has also examined some samples of annatto, and found them to be adulterated with *rye* and *barley* flours, *turmeric*, *salt*, *red earth*, and *carbonate of lime*.

Lastly, the following analyses by Dr. Bernays embody the results of the chemical examination of the ashes of five samples of annatto furnished him by the author:—

No. 1.

Ash of 100 parts, weighed 62·40, which was composed of—

Carbonate of lime	37·88
Sulphate of lime	8·82
Alkaline sulphates	4·34
Chloride of sodium	6·42
Iron and alumina	2·14
Lead, traces, sand, &c.	2·80
	62·40

No. 2.

Ash of 100 parts, weighed 13·70:—

Chloride of sodium	6·87
Sulphate of lime	4·12
Iron and alumina	1·40
Sand, &c.	1·31
	13·70

No. 3.

Ash of 100 parts, weighed 17·20:—

Chloride of sodium	9·30
Sulphate of lime	4·00
Iron and alumina	·90
Sand, &c.	3·00
	17·20

No. 4.

Ash of 100 parts, weighed 13·95:—

Chloride of sodium	4·31
Sulphate of lime	5·92
Iron and alumina	1·32
Sand, &c.	2·40
	13·95

No. 5.

Ash of 100 parts, weighed 62·26:—

Carbonate of lime	42·00
Sulphate of lime	8·84
Chloride of sodium	6·56
Iron and alumina	3·20
Sand, &c.	1·66
	62·26

From what has already been stated, it will be apparent that the whole of the above five samples were adulterated, chiefly with chalk, gypsum, salt, iron, and lead.

The presence of *lead* in annatto has been detected, not only by ourselves, but by Accum, Mitchell, Bernays, and Normandy.

Accum, at page 276 of his 'Treatise,' has written to this effect:—'Several instances have come under my knowledge in which Gloucester cheese has been contaminated with red lead, and has produced serious consequences on being taken into the stomach. In one poisonous sample which it fell to my lot to examine, the evil had been caused by the sophistication of the annatto employed for colouring cheese. This substance was found to contain a portion of red lead.' Accum then goes on to quote the particulars of a case recorded by a Mr. Wright, of Cambridge:—A gentleman, after partaking of some toasted cheese at an inn on two different occasions, was both times made ill by it. The matter was referred to the manufacturer of the cheese, who, on enquiry, ascertained that the annatto which had been used to colour the cheese was itself coloured or adulterated with both vermilion and red lead.

Mr. Mitchell, in his 'Treatise on the Falsification of Food,' published in 1848, states, page 231:—'I have frequently examined specimens of annatto which have been contaminated with red lead or a mixture of red lead and ochre.'

Lastly, Dr. Normandy, in his 'Commercial Handbook of Chemical Analysis,' writes, 'Unfortunately as annatto is very often adulterated with red lead, or with both red lead and ochre, the use of such annatto is very injurious, and serious accidents have been caused thereby.'

Two of the authors quoted, viz., Accum and Mitchell, testify to the fact of the presence of lead in annatto and cheese of their own knowledge. It is not clear whether Dr. Normandy does so or not, or whether he merely repeats the statements of others on the subject. Now there is no evading the evidence of the first two witnesses.

We would further observe that, in some of the samples examined, the ingredients were so badly mixed that in some instances we picked out little masses of the substances added, as of the different kinds of flour used, turmeric, chalk, and red earth.

Now the manufacturers of annatto will doubtless try to persuade us, and perhaps others who are not manufacturers will do so as well, that some of the substances which we have mentioned are introduced to improve the article, to render it more soluble, and to make it keep better. We are ready to admit that the use of alkali is perfectly justifiable to render it more soluble, but beyond this we do not go; and allowing this plea of improvement to have all the weight that can possibly belong to it, enough will still remain to show that annatto is subject to a large amount of adulteration, for it is impossible to justify the use of turmeric, of Venetian red, or reddle, of 40 or 50 per cent. of wheat, barley, or rye flour, and of 50 and over 60 per cent. of chalk and sulphate of lime.

With respect to the plea, which has been urged, that some of the substances added make it keep better, we would remark, that annatto, with ordinary care, will keep perfectly well for months and years without any such addition, and that the substances added are not always effectual. It often remains in the docks before it is sold for one or two years, during which long period it retains its goodness. Thus, while we have never seen a sample of annatto as imported attacked with maggots, several of those which we have purchased at shops were so; and in consequence of the large quantity of salt which they contained, they attracted water to such an extent that they quickly became spoiled. One specimen, which was riddled through with holes, yielded an ash which weighed 12 per cent., and it contained lead and iron. Another sample, one of those sent by Mr. Hogg, was infested with living larvæ, and yet this contained a large quantity of turmeric powder, starch, salt, and a red earth—the ash amounting to 24 per cent., and yielding 1·70 per cent. of iron and alumina, as red as reddle.

Some of the samples examined did not contain more than 30 per cent. of annatto; and could it be shown that the reduction of annatto to this enormous extent was justifiable—which, however, it certainly is not—then it cannot be denied it is high time that the name of annatto should be abandoned, and that some name or names should be adopted which would express the actual composition of the article, and serve to indicate the fact that the article thus reduced consists in part only, and that often the smallest part, of that which it professes to be —viz. annatto.

The late Mr. Wakley, who gave some highly interesting and important information, in regard to adulteration, before the Parliamentary Committee of 1855, communicated the following evidence respecting the annatto sent out by a house to which he was attached in early life:—'It consisted of flag annatto half a pound, powdered turmeric three ounces, powdered lime three ounces, and soft soap ten ounces. But frequently, when there was no flag annatto to be had, an additional quantity of turmeric was put in, with some red colour which I do not now recollect; but often it was sent out without a particle of annatto. The powder for moulding the annatto consisted of eight ounces of whiting and two ounces of Dutch pink.'

We have now advanced enough to prove that annatto is extensively and scandalously adulterated.

At the meeting of the Pharmaceutical Society, to which a paper by the author on the adulteration of annatto was communicated, some years since, Dr. Theophilus Redwood, the present President of the Society of Public Analysts, whose views in regard to conventional adulterations, &c., excited so much surprise, undertook the Quixotic task of proving that the various substances found in adulterated annatto were all added to improve the article, Dr. Redwood not even objecting to the sulphate of copper found.

Of the evidence given before the Parliamentary Committee in defence of adulteration, excepting only that of Dr. Redwood referred to, none was more remarkable than that of Mr. Drew, of the firm of Drew, Heyward, and Barron, wholesale druggists. The few following particulars will serve to show the character of Mr. Drew's evidence:—

He denied that annatto was adulterated, on the ground that it was physically impossible to mix turmeric with annatto, the fact being that nothing is more easy.

In like manner he denied that cinnamon was adulterated, and alleged that cassia was as dear as cinnamon; also that arrowroot was not adulterated, since sago and potato powders were worth as much; and, lastly, he flatly denied that spices were adulterated in any degree, these assertions being unsupported by a particle of proof.

We now come to make a few remarks on the employment of annatto in the colouring of milk and butter, but principally cheese. We would first state we do not apprehend that danger is often likely to arise from the occasional presence of lead in annatto, seeing that the quantity used to colour cheese is but small.

The practice of colouring cheese with annatto entails, however, some expense and trouble, while it serves no really useful purpose, and on these grounds it is to be condemned; but on this point we will cite the opinions of two well-known authorities on dairy farming.

In the 'Rural Cyclopædia,' part i. p. 127, we find, amongst other remarks relating to annatto, the following:—'Another variety of annatto that is commonly employed in English dairies is manufactured in Brazil into small rolls, each two or three ounces in weight, hard, dry, and compact; brownish without, and red within. But its grand interest to the farmer consists in its very extensive use as a colouring matter for butter, and especially cheese. The cheese-makers of Gloucestershire give one ounce of annatto to one hundred-weight of cheese, and those of Cheshire eight dwts. to sixty pounds. But as these quantities are far too small to medicate the cheese, or even to affect its flavour, the only advantage to be derived from the annatto is mere colour, and surely the appearance of Stilton or Dunlop cheese upon the table is to the full as agreeable as that of Gloucestershire or Cheshire cheese. The use of annatto, therefore, is sheerly whimsical, imposing perfectly useless trouble on the manufacturer, and some small ridiculous expense upon the purchaser. The mode of using it is to dissolve it in the hot milk immediately before churning.'

Mr. Stephens, in his 'Book of the Farm,' part iii. p. 288, makes some observations on the use of annatto to colour cheese, nearly to the same effect. He says:—'I have not recommended the use of annatto, or arnotto, for dyeing cheese, because I think by it the cheese farmers impose upon themselves a very useless piece of trouble. All the quantity employed is said to impart no peculiar flavour to the cheese; which being acknowledged, of what utility is it?'

THE DETECTION OF THE ADULTERATIONS OF ANNATTO.

Organic adulterations.—Annatto in the manufactured state presenting so few evidences of structure, it is a very easy matter indeed, by means of the microscope, to detect the presence in it of most foreign vegetable substances, as *turmeric powder*, and the *starch* of *wheat*, *rye*, *barley*, and *sago flours*.

The turmeric, owing to the action of the salt and alkali usually present with it in the annatto, is generally much changed; most of the colouring matter of the cells is discharged, so that the starch corpuscles contained within them become visible; loose starch granules of turmeric may also be frequently seen presenting their usual characters, except that they are much increased in size in consequence of the action of the alkali upon them (fig. 202).

The characters of turmeric powder will be found described in the report on that article, while the characters of the different starches are given under their respective heads.

Inorganic adulterations.—The presence of most of the *inorganic adulterations* is in many cases sufficiently manifest by the appearance, weight, and taste of the ash. Thus the weight of the ash generally serves to show the presence of sulphate and carbonate of lime; the colour, the presence of the red earths; and the taste, the salt and alkali; the presence of salt can indeed generally be ascertained by the taste of the annatto itself. Sometimes, however, a quantitative examination is required.

The inorganic substances for which annatto has to be tested chemically are *sulphate* and *carbonate of lime*, *carbonate of potash*, *carbonate of soda*, *chloride of sodium*, *red ferruginous earths*, *lead*, and *copper*.

As several of these substances sometimes occur in the same samples, we shall not describe the processes for the detection of each separately, but shall sketch the outlines of a combined analysis.

Incinerate 10 grammes of the annatto, weigh the ash, pulverise; treat with two or three successive small portions of distilled water; this will separate the chloride of sodium and the carbonate of soda or potash, should either of these be present; and the quantities of which may be estimated as follows:—

Divide the solution into two parts; precipitate from one the chlorine of the salt by means of nitrate of silver, and calculate the chloride of silver formed into chloride of sodium. Estimate in the other portion of the solution the alkalinity by means of a standard solution of sulphuric acid, and calculate for carbonate of soda; but if there be any doubt as to whether the alkali be soda or potash, we must proceed as directed under the head of 'Tea.'

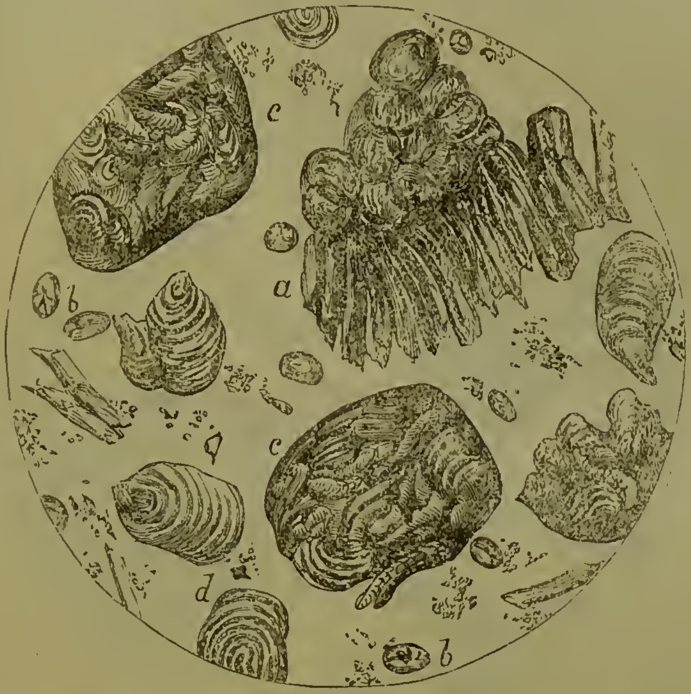
Transfer the portion of the ash insoluble in water to a glass flask, boil in as small a quantity as possible of pure but dilute nitro-hydrochloric acid; dilute with water, filter; weigh the residue insoluble in the acids, and deduct it from the gross weight of the ash—it will consist of silica, sand, and some unburned carbon.

Divide the solution into two parts; from one throw down the sulphuric acid, if present, by means of chloride of barium; collect, wash, ignite, and weigh; from the other precipitate the lime with oxalate of ammonia; calculate the sulphuric acid into sulphate of lime; if there is any excess of lime, calculate it into carbonate of lime.

We have now only to estimate the *alumina* and *iron, lead,* and *copper.*

For the determination of these it is best to operate upon another portion of ash; dissolve with heat in *dilute* nitric acid, evaporate nearly to dryness, dilute with water, and divide the solution into two portions.

Fig. 202.



Annatto adulterated with *turmeric.* Magnified 225 diameters. *a*, outer part of seed; *b*, starch granules; *c c*, cells of turmeric; *d d*, free starch granules of same, but much altered by the action of the alkali.

Estimate the iron and alumina in one portion in the manner directed in the article on 'Tea.'

In the other, determine the copper and lead quantitatively as follows:—

Separate the lead from the copper by means of pure dilute sulphuric acid, added in slight excess; the precipitate must be washed first with water acidulated with sulphuric acid, and finally with spirits of wine; dry, ignite, and weigh.

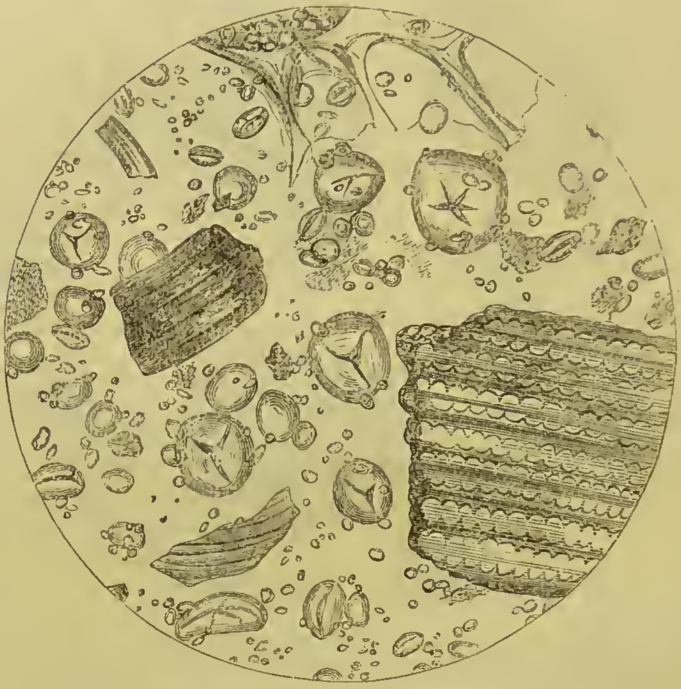
Precipitate the copper by means of sulphuretted hydrogen; collect, dry, weigh, and calculate into the sulphate.

Or the following process may be adopted for the separation of the lead :—Mix the concentrated nitric acid solution with hydrochloric acid in excess ; add a large quantity of absolute alcohol mixed with some ether ; let the precipitate subside, filter the fluid off, wash the precipitate with alcohol and ether, dry it at a gentle heat, and weigh.

The following process for detecting and estimating minute quantities of oxide of copper is by Mr. Warington :—

'This operation depends upon the solubility of the ferrocyanide of copper in an excess of a solution of ammonia, and its deposition with its well-marked characteristic appearances as the ammonia evaporates. Thus, supposing a frequently occurring case, where the oxide of copper, in very small quantity, is in solution with oxide of iron, and that these metals have been brought to their highest state of oxidation; ammonia is next added in excess, and then a few drops of a solution of the ferrocyanide of potassium, and the whole thrown upon a filter. As the ammonia escapes from the filtrate by standing and free exposure to the air, the red ferrocyanide of copper will be deposited, and if the experiment be made in a shallow white porcelain dish, the

Fig. 203.



ANNATTO adulterated with *rye flour.* Magnified 225 diameters.

result will be very distinct and characteristic, and on carefully decanting the fluid, the precipitate will be found on the white surface. In many cases, the process of filtration may be dispensed with altogether, as the suspended peroxide of iron does not in the least interfere with the deposition of the ferrocyanide of copper from the solution. I have found this test gives unerring indications in cases where no trace of blue colour could be distinguished in the ammoniacal solution, and where no precipitation could be procured by hydrosulphuric acid gas or the action of a voltaic circuit.

'When organic colouring matter is present, this form of test is also very useful, as in vinegars, &c.'

CHAPTER XXXVIII.

VINEGAR AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Free sulphuric acid beyond the quantity allowed by law, or any other mineral acid, or vegetable acid, excepting acetic acid, derived from the manufacture of the vinegar. Water in such proportion as to reduce the acetic acid to below 3·5 per cent. It is questionable whether it would not be well that the law should be abolished which allows of the addition of 1 part of sulphuric acid in 1,000 parts of vinegar.

Acetic acid is the volatile principle, to the presence of which, diluted with variable proportions of water, vinegar mainly owes its aroma and pungency.

This acid exists, ready formed, in notable quantity in certain plants, as *Sambucus niger* or *black elder*, *Phœnix dactylifera* or *Date tree*, and *Rhus typhenus*.

It may be readily generated by the fermentation of various vegetable and animal substances, especially the former.

For commercial purposes it is made from certain vegetable and spirituous infusions, as those of the grape, malt, and the sugar cane: but any vegetable infusion capable of yielding alcohol will also, when exposed to the necessary conditions, furnish vinegar. In most cases, when vinegar is manufactured on a large scale, the vinous or alcoholic fermentation precedes the acetous, and the vinegar is formed entirely at the expense of the alcohol.

Acetic acid may be formed directly from the vapour of crude alcohol or spirits of wine in contact with the atmosphere, either by means of an ignited platinum wire, or of the black powder obtained by boiling proto-chloride of platinum and potash with alcohol. In Germany, where the price of alcohol is very low, vinegar has been manufactured on a large scale on this principle. The process will be found described at page 368 of 'Food and its Adulterations.'

Certain conditions are either essential to acetification, or else promote greatly the rapidity of the process; thus the presence of *atmospheric air* or *oxygen* is one of the conditions indispensable to the change, the reason of which will appear from what follows.

Common or ethylic alcohol, C_2H_6O, by the absorption of 2 atoms of oxygen from the air, yields acetic acid, $C_2H_4O_2$, and one molecule of water. This process takes place in two stages. First one atom of oxygen deprives the alcohol of 2 atoms of hydrogen, *aldehyde*, C_2H_4O, being formed. This in its turn absorbs 1 atom of oxygen and yields directly acetic acid; usually, however, especially when the access of air is limited, a portion of the aldehyde escapes oxidation into acetic acid. But in most cases small quantities of acetic ether and other volatile substances are produced, giving to the vinegar much of its flavour and aroma.

Such are the changes of alcohol into acetic acid.

It is therefore evident that much of the success of any process adopted for the manufacture of vinegar will depend upon the manner in which the mother liquor is exposed to the atmosphere—that is, upon the constant renewal of the air, and the extent of surface exposed to its action, the conversion of alcohol into acetic acid taking place only on the surface of the liquid.

A second condition which greatly facilitates acetification is the presence of a *ferment.*

In vegetable infusions, as those of the grape and malt, the nitrogenised principles contained in them act as the ferment. Vinegar itself, vinegar yeast, lees, beer yeast, leavened bread, and many other similar matters, are capable of exciting fermentation, and so promoting the generation of acetic acid. Experience has shown that the best ferment for inducing the transformation of alcohol into acetic acid is a portion of ready-made vinegar itself.

A third condition, which, though not, like the former, essential, yet greatly hastens the conversion, is an increased temperature, varying considerably in different cases, but being often about 38° C.

When any spiritnous liquor is exposed under the conditions requisite for acetification, the following phenomena are observed to occur in succession.

However clear the liquid may have been at first, it quickly becomes turbid; currents or movements are soon visible in it; it is said, in common language, to be 'on the work.' Slimy particles collect on the surface, gradually forming a scum, which, after a time, falls as a sediment to the bottom. The Germans call this scum 'vinegar mother,' since it is capable of exciting acetification in fresh portions of liquid. During the process the temperature of the liquid rises, and the peculiar aroma of vinegar becomes diffused in the surrounding air; as soon as all the alcohol has become converted into acetic acid, the temperature falls to that of the atmosphere; the motion ceases, the liquid becomes clear and bright, and its conversion into vinegar is complete.

The different kinds of vinegar may, according to their source, be divided and classified as *malt*, *wine*, *cider*, *beet*, *sugar*, and *wood vinegars*, but occasionally other fruits, as *gooseberries* and *currants*, are employed for the manufacture of vinegar.

Malt vinegar.—An infusion of malt is prepared in the same way as the wort for the brewing of beer—namely, by exhausting the crushed malt with successive quantities of water, which has previously been heated to about 70° C. The solution is allowed to cool to about 25° C., and to 100 gallons from 3 to 4 gallons of yeast are added.

There are two essentially different methods of the further treatment of this liquid. Formerly it was filled into casks which were placed in rows in an open field, which were allowed to remain there for many weeks, until the acetification was complete. This process, called *fielding*, was begun in the early months of the year, and was not completed till the autumn. The casks are filled from the top of the brewhouse by means of a flexible pipe. After the completion of the acetification, the casks are emptied by means of a syphon into a trough placed beneath, and the liquid is pumped by means of steam up to the brewhouse and into the *refining* casks. These casks are filled with stalks and skins of grapes, or with wood shavings, straw, or spent tan, and the vinegar is allowed to filter several times through these substances. By this process the vinegar is freed from nitrogenous matters, and rendered clear and bright. It is then pumped into vats, where it remains until it is filled into casks for sale.

The other method of acetification of the wort, which has now superseded the fielding process, is as follows:—Large casks placed in three or four ranges over each other in a room or cellar warmed from about 28 to 30° C. are filled to about one-third of their capacity with ready-made vinegar, to which about 2 gallons of wort are added. Every week an addition of two gallons more is made. After four weeks 8 gallons of vinegar are drawn off, and, as before, wort is added two gallons at a time to the liquid in the casks. These casks are pierced with two holes, one at the top to allow of the insertion of a funnel to fill them, the other is at the side, a little above the surface of the liquid, to permit the escape of the carbonic acid formed during the fermentation of the sugar and the entrance of air.

More than two-thirds of the capacity of the cask should not be filled with the liquid, so as to expose as large a surface as possible to the action of the air. These casks are used for many years successively.

Malt vinegar prepared by either of the above described processes possesses a yellowish-red colour, an agreeable aromatic odour, and a strongly acid taste. We believe, however, that at the present day vinegar is rarely made from malt only, but from a mixture of malt with other grains, and even with sugar and treacle.

Wine vinegar.—From both red and white wines of inferior quality vinegar is prepared in wine growing countries, especially in France. The method employed for its manufacture is in its details nearly the same as that described under malt vinegar—namely, the acetification is carried on in heated rooms, a portion of the liquid being from time to time drawn off from the casks, whilst an equal addition of wine is made to the remaining liquid. Large quantities of cream of tartar are in the course of time precipitated upon the inner surface of the casks. It has been observed that the formation of acid is hastened by slight continual motion.

The casks used at Orleans are capable of holding about 400 pints of wine, which is mostly used when it is about a year old, as old wine, having lost its nitrogenised constituents, does not so readily undergo acetification.

Wine vinegar is of course either white or red, according to the colour of the wine from which it is prepared. It is superior to the other kinds of vinegar, it containing all the flavour and aroma of the wine from which it has been made.

Wine vinegar is sometimes flavoured by the addition of wine, the presence of the alcohol increasing its aroma and pungency.

Too great reliance must not be placed upon the presence of bitartrate of potash in vinegar as a proof that the vinegar is really made from wine, as this salt is not uncommonly added to other descriptions of vinegar, especially sugar vinegar; it is even added sometimes to malt vinegar.

Sugar, beet, and cider vinegars.—Vinegar is frequently prepared on a large scale from the above substances, as also occasionally from fruits other than the apple, as pears, gooseberries, currants, &c. The vinegar made from apples, pears, and other fruits is distinguished by the presence of *malic acid.*

Dr. Stenhouse has even recommended the use of *seaweed* for the manufacture of vinegar. This, when subjected to fermentation with the addition of lime, yields acetate of lime, which may be decomposed with sulphuric acid, thus furnishing a more or less pure acetic acid.

Distilled vinegar.—By submitting wine or malt vinegar to distillation, the acetic acid and all the volatile constituents are obtained in the distillate, which is known as *distilled vinegar.* It should be remembered, however, that the vinegar thus obtained is always weaker than that from which it is derived, and this because the boiling-point of vinegar is higher than that of water. The distilled vinegar of wine often contains a small quantity of alcohol.

The Vinegar Fungus.

A very pure and wholesome vinegar may also be prepared from a solution of sugar or treacle, fermented by the agency of a fungus termed *the vinegar plant.*

We were favoured some years since by Mr. Fletcher, surgeon, of Bromsgrove, with the following particulars in reference to the vinegar plant:—

'A few weeks ago I had a young vinegar plant sent me, with the following directions:—"Put the plant in an earthen jar, add to it half a pound of the coarsest moist sugar, and half a pound of treacle, with five pints of milk-warm water; cover it lightly over, so as to keep out the dust, but not the air, and then put it in a moderately warm place; there let it remain seven weeks, not disturbing it more than you can help. At the end of that time pour off what is now the clear vinegar, and keep it in well-corked bottles for use. Again add to the plant the same quantity of water, sugar, and treacle, as before. At the end of the second seven weeks, the plant will have become like two thick pancakes, and they may be easily divided, care being taken not to tear the old or new plant. If the plant is exposed to the cold, or kept too long out of the liquid, it will become black and die."

'I herewith send you,' continues Mr. Fletcher, 'a sample of vinegar thus manufactured. Should the sample be worthy of your attention, I will send you a larger quantity of vinegar, a young plant, and a sample of pickles made with this kind of vinegar.'

In a second letter Mr. Fletcher writes:—'The plant I have was given me early in the winter, and it not only has supplied me with several young plants for friends, but vinegar enough to last me for years.'

We have been given to understand that vinegar plants are sold in large numbers by the chemists in Manchester and the surrounding towns, and that vinegar is made in considerable quantities by means of this fungus. We also know that since the publication of the fact that vinegar may be thus prepared, many persons have been led to try this plan, and for the most part with very satisfactory results.

The Quick Vinegar Process.

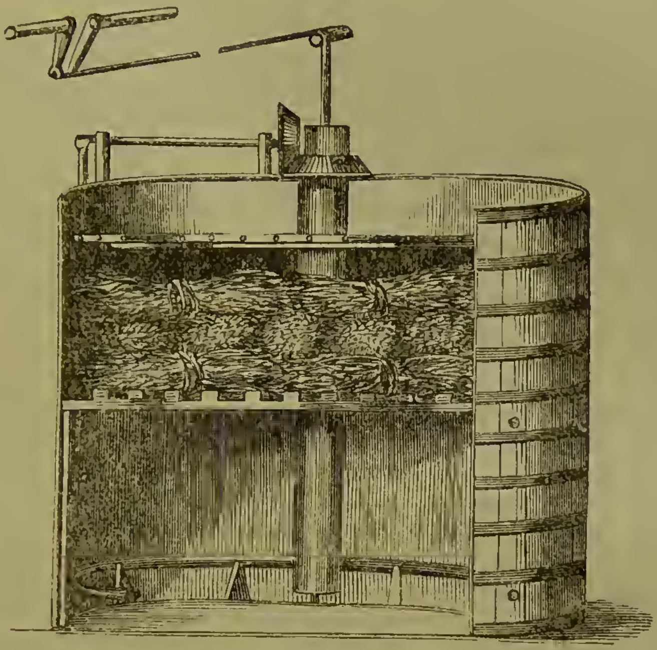
The knowledge of the fact that atmospheric air is indispensable to acetification led to the adoption in this country and in Germany of what has been termed *the quick vinegar process*, by which the liquid to be converted into vinegar is kept constantly in motion in a divided state, and thus a large surface is continually exposed to the action of the atmosphere.

Some years since we had the opportunity of seeing this improved process in full operation at the vinegar manufactory of Messrs. Hill, Evans & Co., of Worcester, and more recently at those of Messrs. Slee, Slee & Co., and Messrs. Crosse & Blackwell.

The process is conducted in large vats, capable of each holding from 6,000 to 10,000 gallons of wash; each vat is half filled with the liquid to be acetified, and the upper half with bundles of birch, such as are in general use for brooms or besoms. The pump in the centre elevates the liquor, and, by means of its rotative motion, disperses it in a shower over the surface of the bed of birch, and in descending through the same it is met by a small ascending current of atmospheric air, which, coming in contact with the multiplied surfaces of the liquor trickling through the twigs, speedily acetifies it; the whole being kept up to the proper heat by a steam-pipe of pure tin passing through the vat. The acetification is generally completed in twenty days, but varies in inverse ratio to the proportion of birch to the wort to be acetified; and the whole operation, mechanical and chemical, being performed by steam, no manual labour of any kind is required save the occasional inspection by the manager to ascertain when the process is finished.

In place of the birch twigs, wood shavings and wood charcoal have sometimes been employed.

Fig. 204



Acetifier Model.

This apparatus is capable of acetifying any fermented liquor whatever, and even distilled spirit, with a complete control over any waste.

The process will be more clearly comprehended by an examination of the accompanying engraving, which was made from a model prepared by Messrs. Hill, Evans & Co., and shown at the Great Exhibition.

The upper circular opening in the side of the vat is for the admission of atmospheric air, the lower is the termination of the steam-pipe. It should be mentioned that the principle of the process was discovered quite independently, and about the same time, in Germany and in this country.

Manufacture of acetic acid from wood.—Billets of wood, usually those of the oak, ash, birch, or beech, are subjected in retorts, analogous to those used in the manufacture of gas, to destructive distillation. Various gases and volatile compounds are thus formed. These are passed through a series of condensers, which retain the water, tar, methylated spirit, and acetic acid, while the uncondensable gases are conducted into the fire, to the heat of which they contribute by their combustion. The liquid in the condensers is distilled, when the methylated alcohol first passes over and then the acetic acid, together with a portion of the tarry matter and other impurities, the object of the subsequent treatment being to free the acid, termed in its unpurified state *pyroligneous acid,* from these contaminations.

The second portion of the distillate, containing the crude acetic acid, is neutralised with either carbonate of soda or carbonate of lime. When the latter is used, the acetate of lime formed is in its turn decomposed by means of sulphate of soda, readily crystallisable acetate of soda being formed and sulphate of lime, which, for the most part, is deposited. The solution is now concentrated, when the acetate of soda is obtained by crystallisation. The crystals are further purified by solution and recrystallisation.

Lastly, they are decomposed by the addition of sulphuric acid, sulphate of soda being formed, and the acetic acid liberated and obtained in a separate form by distillation.

Another process which, although cheaper, yields a product of less purity, has been proposed by Völkel, in which he directly saturates the liquid from the condensers with lime. The tar is separated in part, and the liquid, after concentration, slightly acidulated with hydrochloric acid. This occasions the precipitation of a further portion of the tarry matter. The liquid is then evaporated to dryness and distilled with hydrochloric acid, acetic acid, contaminated with hydrochloric acid, passing over. This latter may be removed by the addition of a small quantity of carbonate of soda and redistillation.

Properties of acetic acid.—The acid, as usually obtained by distillation, is more or less mixed with water. In its most concentrated form it crystallises at or below 15° C. in prismatic or tabular crystals. Its specific gravity in the solid state is 1100 at 8·5° C. It melts at 16° C. (Lowitz), at or above 22·5 (Mollerat). It boils at 119° and, according to Kopp, at 117·3° C. It has a very sour taste and odour, blisters the skin, and acts as an acrid poison. It does not redden litmus, unless mixed with water. The vapour is inflammable and burns with a blue flame.

It mixes with water in all proportions, the density of the mixture varying with the amount of acid contained in it. It also mixes freely with alcohol. It dissolves resins, gum resins, camphor, and essential oils.

Different qualities of vinegar.—Nearly all vinegar makers supply at least four different strengths or qualities of vinegar, named respectively Nos. 24, 22, 18, and 16, the first being the strongest, and the last the weakest.

No. 24, or standard vinegar, as it is termed, has frequently its strength increased by the direct addition of acetic or even pyroligneous acid.

No. 22 is in most cases the strongest vinegar really manufactured; the other and weaker kinds being prepared from this by the addition of certain quantities of water.

Further, these numbers do not indicate *absolute*, but merely *relative* strengths, so that the vinegars of different makers having the same number vary considerably in the amount of acetic acid contained in them.

It is thus evident that, according to this system, much inducement for sophistication on the part of retail dealers is removed, who, if they wish to be supplied with a poor and cheap vinegar, have only to order a cask of the Nos. 18 or 16 vinegars of any of the makers.

It is generally stated that good vinegars, such as all Nos. 24 ought to be, should contain 5 per cent. of anhydrous or pure acetic acid.

The goodness of a vinegar is indicated to some extent by its specific gravity. No. 24 vinegar of good quality should have a specific gravity of not less than 1022, No. 22 of 1020, No. 20 of 1019, No. 18 of 1017, and No. 16 of 1015.

THE ADULTERATIONS OF VINEGAR.

The principal adulterations of vinegar are with *water*, *sulphuric acid*, *burnt sugar*, and sometimes with acrid substances, as *chillies* and *grains of paradise*, and also with *acetic* and *pyroligneous acids*.

The water is added to increase its bulk, sulphuric acid and acrid substances to make it pungent, and burnt sugar to restore the colour lost by dilution.

Some of the vinegars sold at small hucksters' shops, and at oyster stalls, consist of little else than diluted sulphuric acid and water coloured with burnt sugar.

Now, the law allows the addition of one part of sulphuric acid to 1000 of vinegar, and it is only when the quantity exceeds that amount that it can be considered as an adulteration; and this it very frequently does.

The use of this quantity of sulphuric acid was permitted on the plea, urged by the manufacturer, that it was necessary in order to make the vinegar keep. That it is not requisite to the preservation of well-made vinegar is shown by the circumstance that several manufacturers, especially those who make use of the quick vinegar process, do not use sulphuric acid at all; and yet the vinegar made by them keeps perfectly well.

As has already been noticed, the same practice prevails in the article vinegar as in mustard; no less than four, and even five qualities of vinegar are made, differing only in strength; the consequence of this system is, that if you buy vinegar at several different shops, it will be found that some of the vinegars will contain two or three times less acetic acid, the active ingredient of the vinegar, than others, although the same price is paid for them all. This system, therefore, affords great facilities for imposition.

Very commonly, after the manufacture of the vinegar has been completed, the strength is brought up by an addition of acetic acid. We are of opinion that this practice is to be regarded as an adulteration. To allow of this addition would be to acknowledge that a mixture of acetic acid and water really constitutes vinegar, which is far from being the case, since genuine vinegar contains extractive matters of different kinds as well as certain volatile principles, and which affect both the aroma and the flavour.

Other adulterations described in books, the majority of which are probably of unfrequent occurrence, consist in the addition of *nitric*, *hydrochloric*, and *tartaric acids*, *alum*, *salt*, *spurge flax*, *mustard*, *pellitory*, and *long pepper*.

Vinegar is not unfrequently contaminated with *arsenic*, this being introduced through the sulphuric acid used in its adulteration.

'You get arsenic,' states Mr. Scanlan, in his evidence before the Parliamentary Committee of 1855, 'in oil of vitriol to a great extent. This arises from the employment of pyrites instead of sulphur. Oil of vitriol is made in large quantities by alkali makers, and when the price of sulphur is high they use pyrites instead; and pyrites almost invariably contains arsenic. Irish pyrites contains a good deal; but I have understood that the Cornish pyrites contains still more. Some few years ago I found an enormous quantity of it in sulphuric acid here in London. It finds its way into muriatic acid made from that sulphuric acid, or in the manufacture of which that sulphuric acid is employed, and hence it may be very mischievous. A mixture of muriatic acid and soda has been used in bread, and I have seen muriatic acid containing a very fearful quantity of arsenic.'

Since the date when the above quotation was written, the manufacture of sulphuric acid from pyrites has entirely superseded that from sulphur.

The following evidence in regard to the use of *corrosive sublimate* was given by Mr. Gay before the same Parliamentary Committee:—

'Corrosive sublimate has been used for years and years in some houses, and not a cask has gone out without a certain proportion of corrosive sublimate.

'*Chairman*. Do you believe that corrosive sublimate was mixed with the vinegar in injurious proportions?

'I do; it was done to give strength to the vinegar. When the D. W. and O. V. have been used, the corrosive sublimate is put in to give it a tartness again in the mouth.

'*Chairman*. Are these technical expressions in the trade—O. V. for oil of vitriol, and D. W. for distilled water?

'Just so. Corrosive sublimate is called "the Doctor."'

White or distilled vinegar, as it is called, is usually made with water and acetic acid, what is sold as such being rarely distilled at all.

RESULTS OF ANALYSES OF SAMPLES.

The chemical analysis of *thirty-three* samples of vinegar purchased of various tradesmen resident in London, furnished the following results:—

1. That the amount of acetic acid, the most important constituent of vinegar, varied greatly in different samples, the highest percentage being 5·10, and the lowest 2·29, or less than half the first amount.
2. That, since the standard No. 24 vinegars, submitted to analysis, ranged for the most part considerably over four per cent., vinegar to be deemed good ought to contain certainly *not less* than four per cent. of real acid.
3. Judged by this standard, out of twenty-three samples of vinegar purchased of dealers in London, seven reached this strength, and contained from four per cent. upwards of acetic acid; the percentage of seven of the vinegars ranged between three and four; while in the remaining nine the amount of acid varied from two to three per cent., it being in two instances as low as 2·40 and 2·29.
4. That twelve samples out of the thirty-three analysed contained no free sulphuric acid—a fact affording convincing proof that the use of this acid, so objectionable in many respects, is not necessary for the preservation of well-made vinegar.
5. That in eight samples the quantity of sulphuric acid present did not exceed the amount permitted to be added.
6. That in the remaining cases the amount exceeded this, and in some instances was three or four times as great.

The results of the analysis of a *second series of samples, twenty-ght* in number, of the vinegar of some of the principal vinegar manucturers, were as follows:—

That *seven* of the samples were entirely free from sulphuric acid or oil of vitriol.

That *eighteen* were adulterated with that powerful mineral acid the amount of which was variable, and often very considerable; from ·63, the lowest, to 6·02, the highest, quantity in 1000 parts.

That *two* of the samples contained it in very small quantity only.
That in *three* samples it was present in considerable amount.
That *six* contained it in very considerable amount.
That in *seven* samples it was present in still larger quantity.
That the acetic acid also varied very considerably in amount in different samples, the highest proportion being, in 1000 parts by

measure, 55·66 parts, or 5·56 per cent., and the lowest, 27·63, or only 2·76 per cent.

8. That in *eight* samples the acetic acid was present in amount over *five* per cent., which is above the standard strength.
9. That in *twelve* samples the quantity exceeded *four* per cent.
10. That in *seven* it was over *three* per cent.
11. That in *one* the quantity of acetic acid present was so small as to be *under three* per cent.—that is, but little more than half the proper strength.

The sulphuric acid indicated in the analyses is what is termed monohydrated sulphuric acid, which is in general very much stronger than the commercial acid; every part of the former, therefore, corresponds to a much larger quantity of the latter.

Again, it should be particularly remembered that the acidifying power of the mineral sulphuric acid is greater than that of the vegetable acetic acid; one part of sulphuric acid acidifies a larger quantity of a fluid than the same amount of acetic acid, so that the sulphuric acid present in vinegar does not simply take the place of a similar quantity of acetic acid, but represents one-third more of that acid. Besides, the taste of sulphuric acid is much stronger and sourer than that of acetic acid.

Contamination with Metals.

As in the preparation of acetic acid and distilled vinegar, *copper* stills, *lead*, *zinc*, or *tin* pipes are sometimes, though by no means commonly used, vinegar is occasionally found to be contaminated to a dangerous extent with those metals. As vinegar is capable of acting very energetically, in the course of a few minutes, on most metals, their use in its manufacture ought to be strictly prohibited. Many fatal accidents have resulted from the impregnation of vinegar with metallic poisons. The metal which is, however, most frequently found in vinegar is *iron*.

In order to avoid any risk of metallic contamination Messrs. Crosse & Blackwell make use of pipes of ebonite, wherever their employment is practicable.

DETECTION OF THE ADULTERATIONS AND IMPURITIES OF VINEGAR.

One means which may be adopted of ascertaining the quality of a vinegar is by determining its specific gravity; this may be done either by means of the specific gravity bottle or of the ordinary hydrometer, or else by an instrument constructed on the same principles as the galactometer of M. Dinocourt, already described. The ordinary gravities of vinegars of the several qualities are stated at p. 635. It will frequently be found that the vinegars sold at the shops weigh several degrees less than even No. 16 vinegar, which is the poorest made, and the specific gravity of which is usually 1015. When the gravity is below this, the vinegar is unquestionably adulterated with *water*.

On the determination of the acetic acid in vinegar.—The quality of a vinegar, and whether it is adulterated or not, can often be ascertained by determining the amount of acetic acid present in any sample; the determination is effected by saturation with known quantities of an alkali.

The acid may be first separated from the other constituents, impurities, or adulterations of the vinegar, by distillation; being volatile, it passes off on the application of heat. The quantity of vinegar to be employed is 50 cc., which should be distilled almost to dryness, the acid obtained being then neutralised with alkali, and its amount thus determined.

The process of distillation, however, is tedious, and does not admit of easy application, except in the laboratory of the chemist. Moreover the risk is incurred of a portion of the acid still remaining behind in the retort. The same end can be attained by a different method—thus the alkali may be added directly to the vinegar. The alkali usually employed is soda; it may be used either in the form of the pure crystals of the carbonate, the recently-ignited carbonate, which is preferable, or a solution of caustic soda. The dried carbonate is prepared by igniting the crystallised carbonate in a crucible. The whole of the water of crystallisation should be driven off, and the white powder left heated to redness.

Weighed quantities of the soda should be dissolved in known bulks of distilled water. A convenient quantity of this solution is heated to boiling, so that the carbonic acid evolved on the addition of the vinegar may be driven off. The vinegar is now gradually added from a burette until the reaction is exactly neutral, *i.e.* until neither turmeric is turned brown, nor litmus paper red. From the volume of vinegar employed, and the quantity of carbonate of soda used, we may easily calculate the amount of acetic acid contained in the vinegar.

Or 50 cc. of the vinegar may be measured into a beaker, and a standard caustic soda solution added to it, until litmus is no longer turned red. The litmus must not be directly added to the liquid, vinegar being usually so deeply tinted as not to allow the change of colour to be seen. In such cases litmus paper must be employed. A convenient strength of the soda solution is such that 1000 cc. of it are capable of neutralising 60 grammes or 1 equivalent of acetic acid.

Mr. Mitchell, in his treatise on 'The Falsifications of Food,' states that 'if a drop or two of pure vinegar be placed upon blue litmus paper, the latter will be reddened; but when dried before a fire, the red colour disappears, and the original blue again presents itself.' Although the above statement holds good in respect to pure acetic acid and its solutions, we have yet found that the redness produced by this acid, in the case of certain pure malt vinegars, is not dissipated by the degree of heat which is employed to dry the litmus paper, but on the contrary remains fast.

On the determination of sulphuric acid in vinegar.—Sulphuric acid, as we have said, is very commonly added to the malt and other vinegars prepared in this country, ostensibly for the purpose of making it keep better, but also unquestionably to augment its strength.

We have already expressed doubts as to whether this addition is at all necessary to well-manufactured vinegar, since many makers now dispense with it altogether; as, however, the law has allowed of the addition of a certain amount of sulphuric acid, the presence of this can hardly be treated as an adulteration, although strictly it really is so. By it the acidity of the vinegar is not only increased, but the cost of the article much reduced, and in place of a volatile and aromatic acid, we are made to consume a harsh mineral acid, having none of these properties, and in no way concerned in digestion.

Several statements are contained in books which treat of adulterations, respecting the detection of sulphuric acid in vinegar. Thus, it is said:—

First. If a pen be charged with vinegar containing sulphuric acid, and words written with it, when dried before the fire, they turn black.

Second. When such vinegar is dropped on paper, the spots also become black when dried.

Third. That towards the conclusion of the evaporation of a portion of vinegar containing sulphuric acid, dense fumes of sulphurous acid will be evolved, and the residuum charred.

Fourth. If a drop of the vinegar be allowed to fall into a hot solution of cane sugar, an intense black spot will instantly appear, resulting from the carbonisation of the sugar.

Fifth. That starch or dextrin, being boiled in vinegar containing sulphuric acid, will be converted into glucose, or grape sugar.

Mr. Lewis Thompson adopts the following process for the detection of free sulphuric acid in vinegar, by which one-half per cent. of that acid, he states, may be detected:—'It will be seen, by only exposing a single drop of the vinegar upon a little plate at a steam heat for five minutes, the vinegar containing the sulphuric acid will become perfectly black. A small white plate is put over a vessel containing water, and the water is made to boil, so that the steam plays against the lower part of the plate. Under these circumstances, take a drop of the suspected vinegar, and drop it upon the plate; if it contains oil of vitriol, the vinegar will evaporate, and the acid will concentrate, till it is sufficiently strong to act on the organic matter of the vinegar, on which it acts and chars it.'

Practically, the above tests, although ingenious and interesting on paper, are worthless, since the carbonisation does not really occur in any of the cases described even when the vinegar contains the largest amount of sulphuric acid we have ever met with, namely, 0·60 per cent.; and with respect to the fifth test, the starch or dextrin would be equally converted by any other mineral acid. Mr. Thompson's test is wanting in delicacy, since it will not detect less than 5 parts of acid per 1000 of vinegar.

There is a simple method, however, whereby the presence of free sulphuric acid may be discovered even in as small a proportion as 1 in 10,000. This consists in adding a few drops of the suspected vinegar to a small fragment of cane-sugar and evaporating the vinegar on the water-bath, when the residue will turn more or less black according to the amount of the free mineral acid present.

For the determination of the sulphuric acid quantitatively, the following method is to be adopted:—

Solution of chloride of barium is added in excess to 50 cc. of the vinegar contained in a beaker and heated to boiling. The precipitate, consisting of sulphate of barium, is allowed to settle, is separated by filtration or decantation, washed, dried, incinerated and weighed, and the sulphuric acid calculated therefrom. Thus the *total* amount of sulphuric acid, free and combined, is obtained. Another portion, 100 cc. of the vinegar, is now evaporated in a platinum basin to dryness and the residue is incinerated. This is usually a very difficult operation, the mass being exceedingly apt to spirt and thus to cause loss unless it be very gradually dried. The ash is heated to redness, is then dissolved in weak hydrochloric acid, and the sulphates are estimated by means of chloride of barium as described above. The difference between the two estimations gives the quantity of *free* sulphuric acid; this, being volatile, is driven away during the incineration.

The quantity of free sulphuric acid must be calculated for acetic acid and the amount deducted from the total acid found.

The quantity of combined sulphuric acid met with is subject to great variation, this being due in part to the grain used, but chiefly to the composition of the water employed in the manufacture of the vinegars.

Estimation of mineral acids.—It has lately been recommended to estimate the quantity of *free mineral acids* in vinegar by the employment of a paper coloured with methylaniline violet, the colour of which is destroyed by mineral, but not by organic acids. The process is thus carried out:—

In 50 cc. of the vinegar the total acidity is estimated by means of a standard solution of caustic soda, litmus paper being employed as the indicator.

In a second portion of the vinegar (100 cc.) the acidity is estimated in the same way, paper coloured with methylaniline violet being employed instead of the litmus paper. The alkaline solution is added until the aniline paper ceases to be decolorised. The quantity of solution employed in the latter case gives the amount of the free mineral acids present, while the difference between this amount and that first employed furnishes the datum from which the quantity of acetic acid may be calculated.

Of the adulteration of vinegar with *nitric, hydrochloric*, and *tartaric acids* it is unnecessary to treat at any length, since we are unacquainted with any instances of the use of those acids in the adulteration of vinegar although it is quite possible that they have been and still are used in some rare cases.

On the detection of chillies and other acrid substances in vinegar.—The presence of acrid substances in vinegar may be readily detected. A portion of the vinegar should be evaporated nearly to dryness and the extract tasted, when the presence of any pungent substance will be plainly revealed. For the detection of capsicum, see the article on 'Cayenne.'

On the detection of burnt sugar.—20 or 30 cc. of the vinegar are to be evaporated on a water-bath to dryness, the extract boiled with alcohol, the alcoholic solution evaporated, and the residue tasted: if it be of a very dark colour, and of a bitter taste, burnt sugar is no doubt present.

On the detection of pyroligneous acid.—Pyroligneous acid consists of acetic acid, with creosote and other impurities. As its name implies, it is formed by the destructive distillation of wood; and it usually possesses a smell and taste indicative of its origin. For the detection of this impure acid nothing more is usually necessary than to distil the acid from a portion of the vinegar, to concentrate this by redistillation, and finally to judge of it by the taste and odour. It may, however, be so deprived of its impurities as to be quite free from smell, it consisting entirely of acetic acid, being then undistinguishable from that acid obtained from other sources.

On the detection of bitartrate of potash in vinegar.—Bitartrate of potash is a constituent of wine vinegar, and as we are often called upon to give our opinion as to whether certain vinegars are made from wine or malt, it is necessary that we should be acquainted with the method of detecting and estimating that salt. For directions the reader is referred to the article on 'Wine.'

On the detection of malic acid.—The process for the detection of this acid will also be found in the article on 'Wine.'

On the detection of metallic impurities in vinegar.—Half a litre of vinegar should be evaporated to dryness in a porcelain capsule, and the residue reduced to a white ash; if the ash be brown or rust-coloured, in place of white, it contains iron. The ash should be treated with a few drops of pure nitric acid, distilled water being added after boiling: the solution should be filtered, and a portion of it tested with sulphuretted hydrogen. If it turn black, the vinegar most probably is contaminated with lead or copper; and if yellow, with tin or arsenic.

The precipitate, if any, is separated by filtration, washed with water containing some sulphuretted hydrogen in solution, and then treated with some sulphide of ammonium. This will dissolve the sulphide of tin and arsenic, while the sulphides of lead and copper remain undissolved, should they be present. The latter are separated by filtration and the filtrate is acidulated with hydrochloric acid, which again throws down the sulphides of tin and arsenic. These are washed with distilled water and then digested with a solution of carbonate of ammonia in which the sulphide of arsenic is soluble. The liquid is filtered and again slightly acidulated with hydrochloric acid. If a yellow precipitate is thrown down, the presence of arsenic is proved. The precipitate of sulphide of arsenic may be weighed and thus the amount of arsenic determined.

The residue, insoluble in carbonate of ammonia, is dried and fused with a mixture of carbonate of soda and nitrate of potash. The fused mass is dissolved in hydrochloric acid, and in the solution a small piece of pure metallic zinc is immersed, upon which the tin is precipitated. When all the zinc has been dissolved the precipitate which subsides is boiled with strong hydrochloric acid, and a few drops of a solution of corrosive sublimate or bichloride of mercury are added. If now a white precipitate consisting of calomel or protochloride of mercury be thrown down, the presence of tin is proved. From the quantity of calomel formed the amount of tin present may be estimated, should it be desired to carry the analysis thus far.

The separated sulphides of lead and copper are now boiled with pure nitric acid, and the solution is evaporated on the water-bath with the addition of a drop or two of sulphuric acid. The copper passes into solution as sulphate of copper, while the lead is thrown down as sulphate, which may be collected and weighed.

If an appreciable amount of copper be present, the colour of the solution will already indicate its presence, but to determine it quantitatively a solution of caustic potash is added. The precipitated oxide of copper may be collected and weighed.

On the detection of iron and zinc.—In the solution of the ash of vinegar, in which sulphuretted hydrogen has either failed to produce a precipitate, or from which the precipitate has been separated by filtration, the *iron* and *zinc* are detected as follows :—To one quantity add excess of ammonia, and then a drop or two of sulphide of ammonium. If a black precipitate is thrown down, iron is proved to be present; another portion is boiled until all the sulphuretted hydrogen is driven away; caustic potash should now be added in excess. The liquid is filtered, and to the filtrate a drop of sulphide of ammonium is added. A white precipitate or turbidity shows that zinc is present. Of course the precipitates in each case should be weighed for the quantitative estimation of these metals.

CHAPTER XXXIX.

PICKLES AND THEIR ADULTERATIONS.

DEFINITION OF ADULTERATION.

Free sulphuric acid beyond the proportion allowed by law in the vinegar with which they are prepared; any other mineral acid; and also copper.

To PERSONS unacquainted with the subject, the title of this report, 'Pickles and their Adulterations,' may appear somewhat singular; and they may be disposed to ask—Are not the gherkins, cabbages, beans, &c., which we see in the bottles, what they appear to be? And are other vegetables than those commonly known to us mixed with the ordinary kinds? To these questions we thus reply—'Gherkins,' on close examination, often turn out to be but shrivelled or sliced cucumbers; the 'young tender beans' to be old and tough; the 'cauliflowers' to have run to seed; and the 'red cabbage' to be nothing more than white cabbage turned into red by colouring matter, as a dyer would change the colour of a dress; further, that amongst the vegetables not unfrequently employed for the purpose of pickle-making are some which do not enter into the calculation of the epicure, as vegetable marrows—which, when cut into pieces, form a very respectable imitation of cucumbers—and sliced turnips, the identification of which would be apt to puzzle even a botanist as well as certainly all those who are uninitiated in the secrets of a pickle manufactory.

But the adulterations to which we more especially allude, and to the consideration of which our attention will be particularly directed in the following remarks, are those which refer to the quality and composition of the vinegar used for pickling, as well as to the means employed for preserving and heightening the colour of green pickles.

In Accum's celebrated work, 'Death in the Pot,' under the head POISONOUS PICKLES, we obtain the following information in relation to the 'greening' of pickles:—

'Vegetable substances preserved in the state called pickles by means of the antiseptic power of vinegar, whose sale frequently depends greatly upon a fine, lively green colour, and the consumption of which, by seafaring people in particular, is prodigious, are sometimes intentionally coloured by means of copper. Gherkins, French beans, samphire, the green pods of capsicum, and many other pickled vegetable substances, oftener than is perhaps expected, are met with impregnated with this metal. Numerous fatal consequences are known to have ensued from the use of these stimulants to the palate, to which the fresh and pleasing hue has been imparted according to the deadly *formulæ* laid down in some modern cookery books; such as boiling the pickle with halfpence, or suffering them to stand for a considerable period in brazen vessels.'

Dr. Percival ('Medical Transactions,' vol. iv. p. 80) has given an account of 'a young lady who amused herself while her hair was dressing with eating samphire pickles impregnated with copper. She soon complained of pain in the stomach; and in five days vomiting commenced, which was incessant for two days. After this her stomach became prodigiously distended, and in nine days after eating the pickles death relieved her from her suffering.'

Among many recipes which modern authors of cookery books have given for imparting a green colour to pickles, the following are particularly deserving of censure; and it is to be hoped that they will be suppressed in future editions of the works from which they are extracted:—

'*To pickle gherkins.*—Boil the vinegar in a bell-metal or copper pot; pour it boiling hot on your cucumbers.

'*To make greening.*—Take a bit of verdigris the bigness of a hazel-nut, finely powdered, half a pint of distilled vinegar, and a bit of alum powder, with a little bay salt. Put all in a bottle, shake it, and let it stand till clear. Put a small teaspoonful into codlings, or whatever you wish to green.'

Mr. E. Raffeld directs: 'To render pickles green, boil them with halfpence, or allow them to stand for twenty-four hours in copper or brass pans.'

'To detect the presence of copper it is only necessary to mince the pickles and to pour liquid ammonia, diluted with an equal bulk of water, over them in a stoppered vial; if the pickles contain the minutest quantity of copper, the ammonia assumes a blue colour.'

The above remarks and quotations convey a somewhat fearful picture of the colouring of pickles.

Results of Analyses of Samples.

Twenty-three samples of pickles of different descriptions, including *mixed pickles, India pickles, gherkins, beans, chillies, &c.*, were subjected to chemical examination, with the following results:—

1. That the *vinegar* used for pickling is often of *a very weak description*, the percentage of acetic acid ranging between 1·48 and 2·91. It will be remembered that in our last report we stated that *vinegar of good quality ought to contain from four to five per cent. of pure acetic acid.*
2. That *nineteen* out of twenty *of the vinegars* submitted to analysis,

poor as they were, *yet owed a portion of their acidity to sulphuric acid*, the amount of which varied in the different samples from ·38 to 2·52 in the 1000 parts; *the largest quantity of this acid being detected in the vinegars in which the red cabbages were pickled.*

3. That *in the whole of the sixteen different pickles analysed for copper*, THAT POISONOUS METAL *was discovered in various amounts: two of the samples contained a small quantity; eight, rather much; one, a considerable quantity; three, a very considerable quantity; in one, copper was present in highly deleterious amount; and in two, in poisonous amounts.*
4. That *the pickles which contained the largest quantity of copper, were those which consisted entirely of green vegetables, as gherkins and beans.*

Notwithstanding the statements made in books, some of which we have noticed at the commencement of this report, we felt convinced when we entered upon these enquiries that so poisonous a metal as copper was now rarely if ever employed for the mere purpose of heightening and preserving the colour of green pickles; we are therefore both surprised and grieved at the character of the results to which our investigations have conducted us. We are happy to state however that since the analyses above recorded were made, very great improvement has taken place; indeed the practice of greening pickles with copper is now being gradually abandoned.

Pickles, doubtless, even when properly prepared, are not very digestible; but we now see that much of the ill effects so generally attributed to their use must result from their impregnation with so poisonous a contamination as copper.

In some cases *copper*, usually the *sulphate*, commonly known as *blue stone*, is added direct to the vinegar in which the pickles are preserved; more frequently, however, no direct addition of copper is made, but a sufficient quantity of that metal, in the form of *an acetate*, is obtained by the repeated boiling of the vinegar in copper vessels, but since vinegar is so commonly adulterated with sulphuric acid, *sulphate of copper* is generally formed as well. Thus it amounts to precisely the same thing whether the copper is added direct to the pickles, or whether it is taken from the copper utensils by the action of the acids of the vinegar.

It is in the vinegar employed for pickle-making especially that we should expect to find *pyroligneous acid;* this acid may sometimes be detected by the slight odour of creosote, from which it is so difficult to free it.

It is of importance that the effect of the action of the sulphuric acid contained in many of the pickling vinegars on the colour of the pickles should be determined. Our own impression is, that it would be found to be injurious.

A visit to a large pickle warehouse, such as that of Messrs.

Crosse & Blackwell, during the season of pickle and preserve making, is not without interest. The vast piles of vegetables and fruit ready to be sorted, cut, boiled, &c., are really astonishing.

It appears, however, that pickle-making is, to a great extent, independent of the seasons, and that most of the different kinds of pickles may be made at any period of the year. This the manufacturers are enabled to do by keeping a large stock of the various vegetables immersed in brine and packed in barrels. In some of our largest establishments many hundred barrels thus filled may be seen. We are informed that the greater part of these vegetables come from abroad. It is alleged that they are kept in brine for the sake of economy, and that they would be preserved far better in vinegar.

THE DETECTION OF THE ADULTERATIONS OF PICKLES.

The processes employed for the detection of all the more usual adulterations of vinegar have already been described, and it is not necessary to repeat them in this place; we have then merely to point out the methods by which the presence of copper in pickles is to be determined.

Detection and Estimation of Copper.

The presence of copper in pickles, bottled fruits and vegetables, and preserves, is often unmistakably indicated by their *colour*.

When the housekeeper preserves these articles, they are usually of a yellow colour rather than green, but as exhibited in shop windows, or purchased of manufacturers of these articles, they frequently present a vivid bluish-green colour, more intense than that of the fresh vegetables or fruit. Whenever these articles are of a decided green, they will almost always be found to contain copper; but when they are yellowish or brownish-green, copper is never present.

This metal is found usually both in the pickles and in the vinegar; and for its detection the following processes may be adopted:—50 cc. or so of the vinegar should be poured into a test-glass, and in this a piece of thick iron wire, having a smooth and polished surface, should be immersed for a few hours. If copper be present it will become deposited upon the wire, forming a coating more or less complete and thick, according to the quantity present. This test may be so readily applied that we recommend the public to make use of it, and so ascertain for themselves whether the pickles they are consuming contain the poison or not. If only a very small quantity of copper be present it will be quickly deposited on the surface of the iron.

For the detection of copper in the pickles themselves, the following process may be adopted.

About 100 grammes of each green pickle, after having been sliced with a glass knife, are to be incinerated, care being taken to avoid very source of contamination; the ash is to be moistened with a few drops of pure nitric acid, 30 cc. of distilled water, after the lapse of a short time, are added, the solution filtered, and treated with excess of ammonia. If copper be present, the solution will become more or less blue, according to the amount.

For the *quantitative estimation of copper* in pickles, we must proceed as follows:—

200 to 300 grammes of the pickles, including a fair proportion of the vinegar, must be evaporated to dryness, then incinerated; the ash treated with about 8 cc. of nitric acid, diluted with an equal quantity of water; the whole boiled for a few minutes, evaporated to dryness, the residue diluted with about 50 cc. more water, boiled again for a time, the solution filtered, and the copper precipitated by means of sulphuretted hydrogen; the sulphuret of copper must be collected, dried, weighed, and the copper determined.

CHAPTER XL.

LEMON AND LIME JUICES AND THEIR ADULTERATIONS.

DEFINITION OF ADULTERATION.

Lemon and lime juice unmixed with alcohol should have a specific gravity of not less than 1034; it should contain not less than 7 per cent. of water-free citric acid, and should furnish nearly 9 per cent. of total solids.

LEMON JUICE is obtained by expression from the fruit of a species of lemon, termed *Citrus limonum*, one of the *Aurantiaceæ*.

Lime juice, which corresponds so closely with lemon juice, is obtained from another species of lemon, called *Citrus limetta*.

Lemon juice consists principally of *mucus*, *albumen*, *sugar*, *malic*, but *chiefly citric acid*, together with certain *saline* and *mineral matters*. According to Buignet, 100 parts of the juice contain 1·1 of grape sugar, 0·4 cane sugar, and 4·7 per cent. of free acid. Good lemon juice should furnish a larger amount of free acid than that named, and should not contain less than, according to Parkes, 5·5 per cent. of acid; but even this amount is far too low, and it should certainly come up to at least the Board of Trade standard, 6·8 per cent. of acid. According to Witt, lemon juice furnishes from 0·2 to 0·5 per cent. of ash, 100 parts containing 44·3 per cent. of *potash*, 2·1 *soda*, 7·6 *lime*, 3·3 *magnesia*, 12·5 *sulphuric acid*, 19·7 *carbonic acid*, 7·6 *phosphoric acid*, 1·0 *phosphate of iron*, 1·2 *chlorine*, and 0·6 per cent. of *silica*.

Lime juice of course approximates closely in its composition to lemon juice, but it is said to have a lower specific gravity, to contain less acid, and also less mucus.

Lemon juice should, according to the British Pharmacopœia, have a specific gravity of 1·039, and it should contain an average of 32·5 grains of acid to the ounce, equal to 7·4 per cent.; but Mr. Stoddart is of opinion that the gravity is too high for the quantity of acid mentioned. He gives the specific gravity as ranging from 1·040 to 1·045, and the citric acid at from 39 to 46 grains per ounce, equal to from 8·9 to 10·5 per cent.

The Board of Trade standard is a specific gravity of 1·030 without spirit, with 30 grains of acid per ounce, equal to 6·8 per cent.

The total solids contained in genuine lemon juice are of course subject to variation within certain limits. Dr. Parkes found in two samples which he analysed 7·186 and 7·1828 per cent., but Mr. Stoddart, according to Parkes, gives a lower amount, 6·17. There must be some error here, inasmuch as the lowest amount of citric acid found by Mr. Stoddart exceeds the total solids met with by him. The ash furnished by the two samples referred to was 0·52 and 0·53 per cent., of which 0·38 was soluble; the potash amounting to 0·12 per cent., or half a grain per ounce, and the phosphoric acid to 0·008 per cent., equal to 0·035 grain per ounce. The total acidity was equal in citric acid to 4·61 and 5·36 per cent., giving an average of 22 grains of acid per ounce.

The alcohol was 5 per cent., equal to about 10 per cent. of brandy.

Witt's analyses give from 0·2 to 0·5 per cent. of ash, of which 44·3 per cent. consisted of potash, so that if the ash was 0·5 per cent., the potash would be 0·9 grain in an ounce.

The phosphoric acid was from 0·015 to 0·038 per cent. These small quantities of potash and phosphoric acid seem to clearly establish the fact that the value of lemon juice does not depend in any way upon those constituents.

Lime juice, as already noticed, has a somewhat lower specific gravity than lemon juice—namely, it is said, 1·037—and it is stated to furnish about 32·2 grains of acid per ounce, equal to 7·3 per cent.

The lemon juice used for shipping, and in fact that usually met with in commerce, is said to be prepared either in Sicily or in the West Indies, and to be mixed with a proportion of spirit, generally brandy or whisky, while olive oil is poured on the top. If the spirit be added in the proportion of 1 to 10, it of course diminishes the citric acid one-tenth, and in making an analysis of lime juice this fact must be held in remembrance. About 1 ounce of brandy is added to 10 ounces of the juice. Sometimes the juice is boiled and no spirit added. Juice of good quality will keep for years, but badly preserved juice will quickly spoil, becoming turbid and mucilaginous, the citric and malic acids being decomposed.

We consider the addition of spirit to lemon juice very objectionable, since in many cases in which the juice is administered the spirit contained in it is likely to exert an injurious effect. Moreover, this addition reduces, as has already been pointed out, to the extent of one-tenth the really valuable constituent of the juice—namely, the citric acid. Another objection is that the spirit enhances greatly the cost of the juice.

Citric acid occurs in a great variety of fruits—in all the various species of *oranges*, *lemons*, *limes*, and *citrons*, in *currants*, *gooseberries*, *raspberries*, *strawberries*, *cherries*, *tamarinds*, *whortleberries*, and many other fruits.

Preparation of citric acid.—This acid is usually obtained from lemon juice. The juice is allowed to undergo a slight degree of fermentation; it is then filtered and neutralised, first with chalk and then with caustic lime, an insoluble citrate of lime being thus formed. Every 10 parts of this salt are decomposed by a mixture of 9 parts of sulphuric acid to 56 of water. The sulphate of lime now formed is washed with cold water, and the filtrate and washings are boiled down in a leaden vessel until the liquor has a specific gravity of 1·13. It is then further concentrated on a water-bath until a crystalline film begins to form; the liquid is allowed to cool, when the citric acid crystallises. If it were further concentrated the excess of sulphuric acid would char the citric acid, and convert the whole into a black mass. The crystals are dissolved and recrystallised four or five times in succession. The mother-liquors are then treated with chalk in the same manner as the fresh lemon juice.

In France the citrate of lime is bleached with chloride of lime before it is decomposed with sulphuric acid. In this country citric acid is usually made from a black, treacle-like liquid imported from Sicily, and which is obtained by the inspissation of the expressed juice of the lemon, after the rind has been removed to be used for the sake of its essential oil.

'To obtain an exportable material for the manufacture of citric acid, Perret treats clarified lemon juice with excess of magnesia; washes the resulting insoluble granulo-crystalline magnesium salt with cold water; redissolves it in hot lemon juice; and evaporates the solution rapidly, whereby a bibasic magnesium citrate is obtained in a form convenient for exportation to the manufactories. G. Schnitzer recommends that the warmed fresh lemon juice be mixed with a quantity of lime or chalk not quite sufficient to neutralise the acid reaction, because an excess of lime likewise precipitates those constituents of the juice which excite fermentation and occasion loss of citric acid. The calcium citrate precipitated as above may, after once washing and rapid drying, be kept for a long time without decomposition. F. Rowe dilutes the concentrated lemon juice imported from Sicily with water, to facilitate the clarification. He also removes the injurious excess of sulphuric acid which accumulates in the concentrated solutions of citric acid obtained by decomposition of the calcium salt, by renewed treatment with lime, whereby flocculent matters, consisting of gypsum and phosphates which interfere with the crystallisation, are likewise removed. A great improvement, introduced by E. A. Pontifex, in the manufacture of citric acid (also in that of tartaric acid) is the use of a vacuum pan for the final evaporation of the solution.'—'Watts's Dictionary.'

Properties of citric acid.—Citric acid, $C_6H_8O_7$, is a tribasic acid, and crystallises in two forms. The one consists of large trimetric prisms, containing one molecule of water of crystallisation. This is its usual form; they effloresce in the air at a temperature between 28° and 50° C., and lose their water of crystallisation at 100° C. The crystals of the second form are deposited from a saturated boiling solution, and they contain 1 molecule of water to 2 of citric acid, the water being, according to some chemists, only mechanically enclosed.

It is soluble in 0·75 parts of cold, and in 0·5 parts of boiling water. It is readily soluble in alcohol, but insoluble in ether.

Lime water added in great excess to a concentrated solution of citric acid occasions a precipitate of citrate of lime. The amount of the precipitate is, however, greatly increased by boiling the mixture, owing to the greater insolubility of the citrate of lime in boiling water; but the citrate is redissolved as the solution cools. It is discriminated from tartaric and racemic acids by the fact that while the acid potassium salts of the latter acids are insoluble, that of the citric acid is soluble in water. But the distinction is further shown by the tartaric acid being precipitated by an ammoniacal solution of chloride of calcium, while citrate of lime is only precipitated after the addition of alcohol.

When a solution of even pure citric acid is kept for some time exposed to the air it becomes covered with a fungus. Further, when mixed with chalk and a little yeast, and subjected to a temperature of from 20° to 30° C., it is decomposed and furnishes *acetic* and *butyric* acids.

Heated in a retort, citric acid melts in its water of crystallisation, and even boils, when the water is given off and condenses in the receiver. At about 175° C. it is decomposed, *carbonic oxide* being disengaged, and *acetone* passes over. The residue in the retort consists of *aconitic acid.* If the distillation be further continued, *carbonic acid* is given off and crystals of *itaconic acid* appear.

Fused with potash it is decomposed into *oxalic* and *acetic acids.* It also yields oxalic acid when heated with strong nitric acid.

Strong sulphuric acid occasions a disengagement of carbonic oxide, and if the temperature be raised, *acetone* and *carbonic acid* are evolved, while the residual mass becomes of a dark brown colour.

By oxidation with permanganic acid, a strongly irritating body, probably *acroleine,* is formed, together with an acid analogous to *acrylic acid.*

Citric acid prevents the precipitation of the salts of iron, manganese, and aluminium, on the addition of alkalies.

THE ADULTERATIONS OF LEMON JUICE.

Water.—Sometimes the strength of the lime juice is greatly reduced by an addition of water, in which case it will be apt to spoil, unless the mixture contain a considerable percentage of alcohol. This adulteration would be discovered by the specific gravity of the dealcoholised juice restored to its original volume, and by the diminished amount of citric acid therein contained.

Sugar.—Another adulteration is with sugar, whereby its flavour is much improved.

Tartaric acid.—This acid, being very much cheaper than citric acid, is sometimes substituted for that acid, either wholly or in part.

Sulphuric acid.—This is by far the most common adulterant of lemon juice, and no doubt its substitution for citric acid is a gross fraud, and one highly injurious to the health of those who partake of the juice thus adulterated. It has been affirmed that the sulphuric acid is added to make the juice keep better, but this object may be effected in less objectionable ways, as by boiling the juice, or covering it with a layer of oil; but it may be questioned whether the addition of sulphuric acid does really cause it to keep for a longer period, since it is very certain that on lime juices which contain free sulphuric acid a scum of penicillium quickly forms, and is thicker and more abundant than on the genuine juice.

Hydrochloric acid.—Another mineral acid sometimes employed is hydrochloric acid, which is also very objectionable as a substitute for citric acid. Furthermore, as has been already more than once mentioned, hydrochloric acid is frequently contaminated with large quantities of arsenic.

Nitric acid.—A third mineral acid which has been said to be used in the adulteration of lemon juice is nitric acid, but we have never met with this adulterant, and we believe, for reasons hereafter given, that its employment is extremely unlikely.

Factitious lemon juice.—Very frequently, in place of the lemon juice being adulterated, acid liquids are substituted for it which do not contain a drop of the juice of the lemon. These liquids may be variously compounded. The usual receipt for the preparation of factitious lemon juice is as follows:—The citric acid is dissolved in water, the solution being flavoured with a spirituous essence of lemon. The flavour of the mixture is, however, not like that of the real juice, while the substitution is discovered by the weight and characters of the residue left on evaporation.

Of twenty samples of lemon juice analysed by Mr. Stoddart, in 1868, seven were genuine, five contained water, eight were artificial, tartaric acid was present in one sample, and sulphuric acid in another.

THE DETECTION OF THE ADULTERATIONS OF LIME AND LEMON JUICES.

In making analyses of lemon and lime juices with a view to detect adulteration, it is necessary to bear in mind the standard or standards which have already been referred to as characteristic of lemon juice of good quality. According to the Pharmacopœia, it should have a specific gravity of 1·039, and should furnish 32·5 grains of citric acid per ounce, equal to 7·4 per cent. But it must be remembered that this applies to the unalcoholised juice, while the Board of Trade standard is a specific gravity of 1·030 without spirit and 30 grains of acid per ounce, equal to 6·8 per cent. of acid.

In making an analysis of a sample of the juice the first thing to be done is to take its specific gravity, which is most accurately determined by the specific gravity bottle. If alcohol be present, the liquid should be evaporated to fully one-half, and restored to its original volume by an addition of water, when the specific gravity is to be again taken.

The points now to be determined are the acidity, the total solids, the amount of mineral matter and the alkalinity of the ash, the percentage of sugar and of spirit.

If all these results correspond with those obtained from the examination of genuine lemon juice, we shall have reason to believe that we are dealing with a genuine sample, but this by no means necessarily follows, as it may possess the right specific gravity, acidity, total solids, and yet not contain a particle of lemon juice. This renders it necessary that the analysis should be carried still further. Thus search must be made for cane sugar, tartaric, sulphuric, hydrochloric, and nitric acids, but especially the first two acids named, and attention must also be paid to the amount and composition of the ash.

We will now proceed to describe the various steps of the analysis.

Acidity.—The acidity is determined in 50 cc. of the juice either by the employment of a weighed quantity of pure carbonate of soda, or, better still, by means of a standard solution of caustic potash containing one equivalent of caustic potash in 1,000 cc. The quantity of alkali used is to be calculated, notwithstanding the presence of a small quantity of malic acid, into citric acid, the chief acid of the lemon juice. 1,000 cc. of the solution of potash saturate 64 grammes of anhydrous citric acid, $C_6H_8O_7$, or 70 grammes of the ordinary crystallised citric acid.

On the detection of citric and malic acids.—Exact chemical methods for the estimation of these acids, especially when they are mixed with other organic acids, do not exist; we merely give, therefore, certain qualitative tests whereby the presence of these two acids can be detected.

The lemon juice to be tested is rendered slightly alkaline by means of ammonia; chloride of ammonium and then chloride of calcium is added, the mixture being well shaken and allowed to stand for some time. If any precipitate appear, this will consist in all probability of tartrate of lime, which is separated by filtration, and to the filtrate three volumes of strong alcohol are added, whereby the citric and malic acids will be precipitated as lime salts. The precipitate is separated by filtration, washed with alcohol, and dissolved in a little dilute hydrochloric acid. The solution is rendered very slightly alkaline by means of ammonia, and is then boiled. A white heavy precipitate, thrown down by boiling, conclusively proves the presence of citric acid. The boiling liquid is filtered, allowed to cool, and again precipitated as above by means of alcohol. The precipitate is boiled with some strong nitric acid. Any malic acid present will thereby be converted into oxalic acid, which, after neutralisation with ammonia, may be detected by the addition of a solution of sulphate of lime. A white turbidity of oxalate of lime establishes the fact of the presence in the lime juice of malic acid.

Total solids.—For the determination of these, 10 cc. are to be evaporated on the water-bath in a weighed platinum basin until the weight becomes constant.

Mineral matter.—The dried solids are now to be incinerated, the ash weighed, and its alkalinity determined with a standard sulphuric acid solution, containing 40 grammes of sulphuric acid in 1,000 cc. The object of determining the alkalinity of the ash is simply to ascertain whether free mineral acids were present in the juice or not. Of course, if those acids, especially sulphuric acid, have been added, the ash will not exhibit an alkaline reaction.

Sugar.—From 200 cc. of the lime juice most of the citric acid is removed by the addition of a solution of basic acetate of lead, an excess of which is to be avoided.

In the liquid, after it has been rendered exactly neutral, the glucose is determined by means of the standard copper solution, in the manner described in the article on 'Sugar.'

Another part of the same solution, freed from the citric acid as above mentioned, is boiled for two hours with a few drops of sulphuric acid, in order to convert any cane sugar which may be present into glucose, which is then to be estimated in the same manner as before. 100 parts of glucose correspond to 95 parts of cane sugar.

Alcohol.—100 cc. of the lime juice are neutralised with caustic soda and the alcohol is distilled off. The specific gravity of the distillate is to be ascertained, and from it the quantity of alcohol present is calculated, as at length described in the articles on 'Beer' and 'Wine.'

Tartaric acid.—50 cc. of the lemon juice are to be neutralised with ammonia, and a solution of chloride of calcium, containing some chloride of ammonium, is added. The liquid is allowed to stand for some hours, when, if any tartaric acid be present, a crystalline precipitate of tartrate of lime, $C_4H_4CaO_6$, $4H_2O$, will be deposited, which may be collected on a filter, washed, dried, and weighed. But it must be remembered that this precipitate may contain sulphate of lime; an estimation of the sulphuric acid in it should therefore be made.

But the amount of tartaric acid is more accurately determined by adding to the lemon juice a solution of acetate of potash and a volume of alcohol equal to that of the lemon juice employed. The tartaric acid will be precipitated as acid tartrate of potash, $C_4H_5KO_6$, if the solution be allowed to stand for 24 hours. Care should be taken not to touch the sides of the glass with the rod, as crystals of the tartrates, which adhere firmly to the glass, are consequently deposited.

Sulphuric acid.—The sulphuric acid is to be precipitated from 50 cc. of the lemon juice by means of a solution of chloride of barium rendered acid by the addition of a few drops of hydrochloric acid; the sulphate of barium is to be collected on a filter, washed, incinerated, weighed, and calculated for sulphuric acid. Genuine lemon juice contains little more than traces of sulphuric acid, and hence for all practical purposes the whole of the sulphuric acid found in the juice may be considered as *free* sulphuric acid.

Hydrochloric acid.—The quantity of hydrochloric acid, like that of sulphuric acid, contained in lemon juice is very small. If, therefore, more than traces be found in a sample, it may be safely assumed that an addition of hydrochloric acid has been made. This is determined by precipitation with a solution of nitrate of silver, as described in the article on 'Water.'

Nitric acid.—The presence of nitric acid may be determined by neutralising the lime juice with pure soda, and reducing the nitrates to ammonia by means of aluminium, as described under the head of 'Water.' The iron and brucine tests may be employed as qualitative tests.

It is extremely unlikely that nitric acid has ever been employed in the adulteration of lime juice, for it would act, even in the dilute state, upon the many organic substances contained in that liquid, and it would itself be reduced to nitric oxide, imparting a disagreeable smell to the article, completely spoiling it, in fact.

One great characteristic of genuine lemon juice consists in the pleasant taste and fragrant odour of the extract.

Results of Examination of Samples.

Lemon Juice.

	Spec. Grav.	Alcohol.	Citric Acid, $C_6H_8O_7$.	Total Solids.	Mineral Matter.	Tartaric Acid.	Sulphuric Acid.	Hydrochloric Acid.
1 Crosse & Blackwell	1035·16	None	7·776	8·990	0·262	None	0·002	Trace
2 Barnes & Co. .	1034·72	”	7·648	8·976	0·314	”	0·002	”
3 H. R. H. . .	1020·96	”	2·728	4·610	0·212	”	0·825	”
4	1035·20	”	7·782	9·270	0·353	”	0·002	”
5	1023·56	”	4·081	7·154	0·110	”	0 001	”

Lime Juice.

	Spec. Grav.	Alcohol.	Citric Acid.	Total Solids.	Mineral Matter.	Tartaric Acid.	Sulphuric Acid.	Hydrochloric Acid.
1 Crosse & Blackwell	1036·04	None	7·168	8·915	0·465	None	0·0021	Trac
2 H. R. H. . .	1018·40	”	3·472	5·055	0·395	”	0·434	”
3	1037·84	”	7·680	9·412	0·473	”	0·0018	”
4	1026·48	”	6·605	8·583	0·390	”	0·002	”
5	1034·92	”	7·155	9·530	0·330	”	0·001	”
6	1038·88	”	7·399	9·670	0·437	”	0·001	”

Of the five samples of *lemon juice* examined, the results of th analyses of which are given above, judged by the Board of Trad standard, which requires a specific gravity of 1030 with 6·8 per cent. of acid, it will be seen that three of the samples exceeded, both in respect to their gravity and in the amount of acid, the above standard, while two were greatly below it, being obviously adulterated, the one with a large quantity of *water*, and the other with both *water* and *sulphuric acid.*

Of the six *lime juices* examined, four exceeded the standard above referred to, while the fifth sample was only slightly below it, and the sixth was adulterated with a large quantity of both *water* and *sulphuric acid.*

It is obvious from these analyses that the Board of Trade specific gravity is too low for the amount of acid which they specify, and that the gravity should not be less than 1034, while the proportion of acid met with in the genuine lemon and lime juices of commerce usually exceeds by nearly one per cent. the standard laid down by the Board.

CHAPTER XLI.

SAUCES AND THEIR ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any free sulphuric acid beyond the proportion allowed in the vinegar with which they are prepared, or any other mineral acid; red ferruginous earths, lead, and copper.

A GREAT variety of substances, chiefly vegetable, enter into the composition of the various sauces in use. The following is an enumeration of the chief of these:—Tomato, garlic, shallot, sorrel, mushroom and walnut catsup, raisins, tamarinds, the seeds of fenugreek and cumin, the leaves of a variety of herbs, as tarragon, chervil, mint, thyme, marjoram, &c., the seeds of an Indian plant called *Dolichos soja* or *soya*, of which soy is made; a variety of spices and condiments, as pepper, Cayenne, mustard, mace, cloves, ginger, and nearly all the other spices; salt, treacle, and burnt sugar as colouring agents, and flour as a thickening ingredient. Out of the above articles, variously combined, and in different proportions, nearly all the sauces in use are compounded. Into the composition of some few, however, animal substances enter, as the muscular fibre of shrimps, lobster, and anchovy.

The following are the chief results deducible from a consideration of the analyses of *thirty-three* samples of sauce of different kinds:—

1. That *treacle* and much *salt* formed the basis of the five samples of INDIA SOY examined, if they did not even entirely consist of these two ingredients.
2. That of the seven samples of TOMATO SAUCE analysed, six were artificially coloured, one probably with *cochineal*, and the rest by the addition of considerable quantities of the ferruginous pigment *bole armenian.*
3. That the samples of ESSENCE OF LOBSTERS examined were saturated with very large quantities of *bole armenian.*
4. That the samples of ESSENCE OF SHRIMPS were impregnated to an equal extent with *bole armenian.*
5. That the whole of the samples of ESSENCE OF ANCHOVIES analysed were adulterated with very large quantities of the ferruginous oxide *bole armenian.*

6. That three of the samples of *Essence of Anchovy* contained but a small quantity of *muscular fibre.*
7. That two of the samples contained a portion of *flour*—one being a sample of essence of shrimps, and the other of essence of lobster.
8. That out of the eighteen RED sauces submitted to examination, no less than sixteen contained *bole armenian,* and this usually in very large quantities, far exceeding the amounts detected in any of the potted meats and fish.
9. That LEAD, for which separate analyses were made in each case, was *not detected in a single instance.*
10. That *traces only of* COPPER *were discovered in some three or four samples.*

The above results, then, regarded as a whole, although bad enough, are yet not so bad or serious as the account given by Accum and some other writers of the adulteration of anchovy paste, &c., would lead us to infer, since lead was not detected in a single instance. There is no doubt, however, but that lead does sometimes occur. Mitchell states, 'several samples which we have examined of this fish sauce, "poisonous anchovy sauce," have been found contaminated with lead.'

Further, it is more than probable that the muscular fibre in several of the samples of anchovy, lobster, and shrimp sauce, consisted either entirely or in part of the fibre of other inferior and cheaper fish.

The only effectual remedy against certain of the adulterations of the sauces, especially the fish sauces, consists in their preparation at home. Receipts for several of the sauces are given at page 512 of the author's work, 'Food and its Adulterations.'

It appears, then, that the red sauces, as shrimp, lobster, anchovy, and tomato sauces, at the time of the analyses the results of which we have just quoted, were almost invariably highly coloured with bole armenian. Since that period however, this practice has, we are happy to state, been nearly abandoned. The ferruginous substance just named is a natural earth, containing a large quantity of the red oxide of iron; but frequently an article is made in imitation of it, consisting of a mixture of Venetian red and chalk. Of this red earth or dirt as much as from 10 to 15 lbs. are added to 100 gallons of anchovy sauce.

Cooks often colour the sauces prepared by them for the table with carmine; this when genuine, is an animal colour, but it is frequently adulterated with *vermilion.*

Perceiving clearly the evils connected with the employment of artificial colouring matters, many of the most respectable manufacturers have, to a very great extent, abandoned their use, except in the case of anchovy sauce, which they state to be unsaleable without a small quantity of the colouring matter. The difference between the ordinary coloured and the uncoloured sauce is very striking; the first is usually bright red — as red, in fact, in some cases, as a brickbat, this redness arising entirely from the introduction of the bole armenian—while the other is usually of a pinkish fawn colour.

The various colouring matters to which reference has already been so frequently made are used not merely for the sake of increasing the colour of the articles, and thus, as it is very often erroneously considered, improving their appearance, but likewise for other purposes, especially to conceal other adulterations; thus, when very large quantities of wheat flour are added to mustard, or flour and sugar to cocoa, the natural colour of those articles becomes so reduced that the addition of some foreign colouring matter is rendered necessary.

Not unfrequently the use of these colouring matters involves considerations of cleanliness; this is so in the case of anchovy sauce. The quantity of refuse matters and dirt contained in the fish from which this is prepared is often very great; and it is the presence of these more than anything else which causes the sauce to present a somewhat unsightly appearance before the red earth is added. It is this circumstance which has chiefly led to the use of the bole armenian; the maker, in place of carefully removing the refuse and dirt, grinds it all up with the fish, trusting to the bole armenian to conceal the impurities, thereby saving himself much trouble and some loss. We are informed by Messrs. Crosse & Blackwell that the impurities which they are obliged to remove in the preparation of the uncoloured anchovy sauce are almost incredible, but that the extra trouble and loss are fully compensated by the greatly improved quality and flavour of the article.

Notwithstanding this improvement in quality, so strong do Messrs. Crosse & Blackwell find the prejudice in favour of the red sauce that many parties absolutely refuse to take the uncoloured sauce—preferring the inferior article simply because of its redness; and Messrs. Crosse & Blackwell have been reluctantly driven again to add a small quantity of the bole Armenian to this particular sauce.

Walnut Catsup.—'Quantities are daily met with, which on chemical examination, are found to abound with copper. Indeed, this condiment is often nothing else than the residue left behind after the process employed for obtaining distilled vinegar, subsequently diluted with a decoction of the outer green husk of the walnut, and seasoned with allspice, cayenne pepper, pimento, onions, and common salt.'—*Accum*, page 319.

CHAPTER XLII.

AËRATED WATERS AND THEIR ADULTERATIONS.

DEFINITION OF ADULTERATION.

The sale of so-called soda or potash waters without their respective alkalies, the presence in lemonade and ginger beer of tartaric acid, bitartrate of potash, or sulphuric acid.

CERTAIN aërated waters and drinks, as soda and potash waters, lemonade and ginger beer, are largely consumed, partly as medicines and partly as pleasant and refreshing beverages. The two last-named partake of the character of articles of food, and all of them are very liable to adulteration, with the nature of which it is very proper that the food analyst should be well acquainted.

It is very important, in the manufacture of aërated beverages, that the water used should be of a high degree of purity, and should especially be free from contamination with organic matter. Some manufacturers are very particular about the quality of the water they use, while others are as careless on the subject and make use of any they can obtain.

Furthermore, great care should be taken that all the vessels used should be of scrupulous cleanness, and that none of these waters should be allowed to remain in contact with lead or any other metal for any length of time. The neglect of this precaution explains the presence of lead and other metals in considerable amount in aërated waters in many cases. Much attention has recently been directed to the presence of metallic contaminations in certain aërated waters.

THE MANUFACTURE OF AËRATED WATERS.

The most complete apparatus as yet devised for the manufacture of aërated and soda waters may be divided into three parts—the generator, the gasometer, and the vessel containing the solution to be impregnated with the gas.

The carbonic acid gas used must be of great purity. It must be free from atmospheric air and from any gas which might give it a perceptible smell. The gas is generated in a leaden cylinder by the action of concentrated sulphuric acid upon either finely powdered marble or chalk, or upon magnesite, which is essentially carbonate of magnesia.

The mixture is constantly kept in motion by means of a stirrer, which passes through a stuffing box on the top of the generator. The carbonic acid escapes through a tube, and is conducted through four vessels, to free it from sulphuretted hydrogen and other gases. The first of these vessels contains a solution of sulphate of iron to remove and destroy offensive gases, including sulphuretted hydrogen, the second a mixture of sulphate of iron and carbonate of soda to absorb oxygen, and the two others pure water. From the last of these vessels, which are made either of strong glass or of tinned copper, the washed pure carbonic acid escapes, and is conducted into a large upright cylinder of tinned copper, about six feet high, and one and a half foot in diameter. This cylinder, before the generation of the gas begins, is filled with water, which by the pressure of the gas produced is gradually forced out. Thus any admixture with atmospheric air is avoided. As soon as this gasometer is quite filled with carbonic acid, water is pumped in from the bottom to about four-fifths of the capacity of the cylinder by means of a force pump, the gas being therefore subjected to a pressure of five atmospheres. The gasometer communicates by means of a tube with the vessel in which the aërated water is to be prepared. This vessel is a horizontal cylinder of tinned copper, capable of holding about 250 pints. It is filled to the top with pure water, and then about one-fifth of its contents are allowed to run out, carbonic acid taking the place. The impregnator is provided with a gauge to ascertain the pressure exerted upon the water contained in it; this, to facilitate the absorption of the gas, is constantly kept in motion by means of a stirrer, the axis of which passes through the sides of the vessel. The gas is now allowed to enter from the gasometer into the impregnator until the gauge shows a pressure of about two atmospheres. The communication is then shut off, and the stirrer is set in motion. The carbonic acid is rapidly absorbed by the water, and the pressure of course diminishes. From time to time this is restored by opening the tap until it permanently reaches two atmospheres, and the gauge shows that the water is now sufficiently saturated with gas; the concentrated saline solution of potash, soda, &c., is introduced into the impregnator through a screw hole at the top of the cylinder, and the pressure is again restored by a fresh addition of carbonic acid.

Lastly, the liquid is drawn off into bottles, a specially constructed tap of brass being employed in order to reduce the loss of gas to a minimum.

An apparatus, similar to that above described, has been constructed by Tyler; but it is in some particulars not so perfect. Thus, he does not pass the gas after its liberation through a series of washing bottles, but directly into the gasometer.

Soda Water.

The British Pharmacopœia directs that soda water should contain 30 grains of bicarbonate of soda to 20 ounces or one pint of water, and that as much carbonic acid should be forced into it as can be introduced by the pressure of 7 atmospheres. Each bottle, therefore, of soda water should contain 15 grains of bicarbonate of soda. But a very large proportion of the soda waters ordinarily sold do not contain a particle of soda; they consist simply of water impregnated with carbonic acid gas, while in the preparation of those which really do contain the alkali no fixed rule has hitherto been observed, and hence the quantity of soda has been found to vary very greatly.

The use of a very hard water for the manufacture of soda water appears to be most undesirable; should the water contain chloride of calcium or magnesium, or the nitrates or sulphates of lime or magnesia, part of these will become precipitated as carbonates with the formation of salts of soda, and a turbidity will be produced in the water which is very unsightly, and which in many cases would render it unsaleable. It is true, however, that the subsequent impregnation of the water with carbonic acid gas serves to redissolve in part the carbonates; but any iron and alumina which the water may have contained, and which had been thrown down by the alkali, would not be taken up again.

Potash Water.

The British Pharmacopœia also gives a formula for the preparation of potash water. This is exactly the same as that for the soda water, so that each bottle would contain 15 grains of carbonate of potash.

The remarks as to the unsuitability of hard water for the manufacture of soda water apply equally to that of potash water. We believe that potash water is rarely met with without its containing more or less of the alkali, although the amount is found to vary greatly in different cases. But now that a standard has been introduced into the Pharmacopœia for the manufacture of these waters, greater uniformity may be expected.

Lemonade.

This beverage should consist of the juice of the *lemon*, a certain amount of the *peel* to flavour it, *white sugar* and *water* in certain proportions, the whole being subjected to fermentation by the addition of a little yeast.

Thus prepared, lemonade is really an alcoholic beverage, the alcohol and carbonic acid being generated at the expense of the sugar, although the amount of alcohol is but small, indeed scarely sufficient to affect the brain of even the most sensitive teetotaller.

But a very common way of making lemonade is to add a proportion of syrup consisting of citric acid and sugar to water impregnated with carbonic acid gas, the sugar not being subjected to fermentation. This beverage would satisfy the demands of teetotallers, since it does not contain any alcohol.

Very frequently, however, lemonade is prepared in ways very different from the above, and by much cheaper formulæ. Tartaric acid and bitartrate of potash are frequently made to do duty for citric acid. Sulphuric acid is in some cases used in conjunction with the tartaric acid and for the same purpose.

Ginger Beer.

Ginger beer—that is to say, the bottled and effervescent beverage commonly known as ginger beer—should be prepared on the same principle as lemonade; the genuine article should not contain anything but *ginger, white sugar,* and *water*, the mixture being subjected, in the same manner as lemonade, to fermentation. If anything further be allowable, it should simply be an addition perhaps of a little lemon or other simple flavouring, with a view to improve the taste of the article. In the case of ginger beer, then, the only acid which should be present is carbonic acid.

Dr. Ure gives the following receipt for the manufacture of ginger beer:—'Boil 65 gallons of river water, 1½ cwt. of the best loaf sugar. and 5 lbs. of the best raw ginger, bruised, half an hour; then add the whites of 10 eggs, beaten to a froth with 2 ounces of dissolved isinglass. Stir it well in, and boil twenty minutes longer, skimming it the whole time. Then add the rinds of 50 lemons, boiling them ten minutes more. Cut 28 lbs. of good malaga raisins in half, take away the stones and stalks, and put them with the juice of the lemon, strained, into the hogshead. Strain the hot liquor into a cooler, and when it has stood two hours and is settled, draw it off the lees, clear, and put it into the cask; filter the thick and fill up with it. Leave the bung out, and when at the proper temperature stir 3 quarts of thick fresh ale yeast well into it; put on the bung lightly and let it ferment six or seven days, filling up with liquor as it ferments over; when the fermentation has ceased, pour in 6 quarts of French brandy and 8 ounces of the best isinglass, dissolved in a gallon of the wine, then secure the bung effectually and paste paper over it, &c. Keep it two years in a cool cellar, then bottle it, using the best corks and sealing them, and when it is four years old commence using it.'

Dr. Ure, in the above receipt, seems to have aimed at the preparation of ginger beer of remarkable excellence and quality; the beverage no doubt would have been good and drinkable very shortly after its manufacture.

We believe that it is a very uncommon thing to meet with a ginger beer compounded simply of sugar and ginger subjected to fermentation. Nearly all the articles sold as ginger beer in the shops contain tartaric acid, bitartrate of potash, or cream of tartar, and even sometimes sulphuric acid.

Another receipt given in 'Ure's Dictionary' for the preparation of a ginger beer is the following:—

Barbadoes ginger root	12 ozs.
Tartaric acid . .	3 ozs.
White sugar . .	8 lbs.
Gum arabic . .	8 ozs.
Essence of lemon .	2 drachms.
Water . . .	9 galls.

The ginger root, bruised, is to be boiled for an hour; the liquor having been strained, the tartaric acid and sugar are added, and the mixture boiled; the gum arabic, dissolved in a separate portion of water, is then added with the essence of lemons. When the whole has cooled to 38° C. some fresh yeast is to be added, and the beer carefully fermented. Then bottle for use.

Pereira gives the following formula, for which he was indebted to Mr. Pollock, for the preparation of ginger beer:—'Take white sugar, 20 lbs.; lemon or lime juice, 18 ounces; honey, 1 lb.; ginger, bruised, 22 ounces; water 18 gallons. Boil the ginger in 3 gallons of water for half an hour; then add the sugar, the juice, and the honey, with the remainder of the water, and strain through a cloth. When cold, add the white of one egg and one half-ounce of essence of lemon; after standing four days, bottle. The bottles are to be laid on their sides in a cellar, and the beer is ready for use in about three weeks. If a little yeast be used, the beer is ready in a day or two, but in this case it does not keep well.'

THE ADULTERATIONS OF AËRATED WATERS.

In the remarks already made under the heads of the chief aërated beverages commonly sold, namely, soda and potash waters, lemonade and ginger beer, we have indicated the principal adulterations to which these several beverages are subject, but we will here again refer to them.

Much of the soda water sold is not soda water at all, since it does not contain a particle of that alkali, but consists simply of water impregnated with carbonic acid gas. In other cases, where the alkali is present, the amount is subject to the greatest possible variation, so that nobody knows, when he partakes of soda water, what amount of alkali he has consumed. The evil of this state of things has led the compilers of the British Pharmacopœia to fix the quantity of carbonate of soda at 30 grains per 20 ounces, or 15 grains to a bottle.

With respect to potash water, we believe that this always contains carbonate of potash, but the quantity, like that of the soda, is subject to great variation according to the fancy or caprice of the manufacturer.

Lemonade, as has been shown, should be made from lemon juice, sugar, and water only, the mixture being subjected to fermentation, by means of yeast, but such lemonade is rarely met with, as the lemon juice is either replaced by citric acid or it contains some other acid besides citric, as tartaric acid, bitartrate of potash, or sulphuric acid; while, lastly, in some cases tartaric acid is substituted entirely for citric acid. Not unfrequently lemonade is made, not only without citric acid, but even without fermentation, the carbonic acid being liberated from *bicarbonate of soda* by the action of an equivalent quantity of *tartaric acid*, an object which is thus accomplished:—The acid and the carbonate, mixed together in the right proportion and in the dry state, together in many cases with powdered sugar, are introduced into bottles filled with water flavoured with lemon peel or essence of lemon, these being, when filled, rapidly corked, so as not to allow of any escape of carbonic acid. The beverage thus prepared is very palatable, but it is of course a very different thing, both dietetically and medicinally, to genuine lemonade.

In beverages thus compounded, the consumer is made to take in many cases a medicinal dose of tartrate of soda or potash.

In like manner, ginger beer should be made of ginger, sugar, and water, also subjected to fermentation.

Metallic Contaminations.

Most aërated beverages, especially soda or potash waters, are liable to contamination with *lead*, *copper*, *tin*, and *zinc*. One or other of these metals has recently been detected in a large proportion of the samples submitted to analysis. These waters may become contaminated in several ways. Thus, as has already been pointed out, the vessel in which the water is saturated with carbonic acid and the soda added is metallic, and is made of copper lined with tin, or even of copper alone. Next, the conducting pipes consist of metal, either lead, tin, copper, or brass, while the taps themselves consist usually of brass. Again there is risk of metallic contamination in the bottling of the waters, whilst the last risk is incurred in the small gazogenes now in such general use, and the construction of which varies so greatly.

Although, as a rule, the carbonates of the above metals are insoluble in water, yet they become readily dissolved in an excess of carbonic acid, bicarbonates being formed.

THE ANALYSIS OF AËRATED BEVERAGES.

Processes have already been given for the detection and estimation of most of the constituents and adulterants of the aërated beverages included in this article.

The amount of *soda* in the soda, and *potash* in the potash water may be estimated by taking the alkalinity of the residue left on evaporation, by means of the standard sulphuric acid solution, containing 40 grammes of sulphuric acid in 1 litre. 1,000 cc. of this solution correspond to 53 grammes of carbonate of soda, and to 69·1 grammes of carbonate of potash.

As it is possible that in some cases one of these alkalies may be substituted for the other, it may be necessary to test the residue qualitatively and then estimate it quantitatively in the manner described in the article on 'Tea.'

In the case of lemonade the acids to be looked for are *citric, tartaric*, and *sulphuric acids.* About 200 cc. are evaporated to one-half, and the acidity determined by the employment of the usual standard solution of caustic soda. The acidity should be calculated into citric acid. We next proceed to discover whether tartaric acid and sulphuric acid are present. The presence of the first is ascertained by the employment of the methods already given in the article on 'Lemon Juice,' while the process for the estimation of the sulphuric acid will be found under the head of 'Water.'

Presuming that *bitartrate of potash* has been used, about 200 cc. of the lemonade should be evaporated to dryness, the residue incinerated, the alkalinity of the ash taken, and if necessary the amount of potash estimated. Should both cream of tartar and sulphuric acid have been added, the solution will contain sulphate of potash and tartaric acid. In this case an estimation of the sulphuric acid as well as of the potash must be made.

As is the case with lemon and lime juice, so with lemonade. This beverage frequently does not contain a particle of lemon juice, but is prepared with citric acid. The discrimination of those cases in which the acid has been substituted for the juice is by no means easy, and would require a minute and complicated analysis, especially an estimation of the potash in the ash.

In those cases in which an effervescing lemonade is prepared by means of *tartaric acid* and *bicarbonate of soda,* about 50 cc. of the lemonade must be evaporated to dryness and the weight and alkalinity of the ash taken. The amount of the ash will, of course, greatly exceed that found in any other description of lemonade.

The analysis of ginger beer embraces very nearly the same determinations, including even the citric acid, as the lemonade.

As we have seen, aërated waters are liable to be contaminated with various metals, these being derived in some cases from the apparatus employed in their manufacture, and in others from the bottles and other vessels in which the manufactured beverage is subsequently enclosed. These metals are lead, tin, copper, and zinc, the latter being derived from the brass tubes and taps employed. The processes to be pursued for the detection and estimation of these metals will be found fully set forth in the article on 'Vinegar.'

Estimation of the carbonic acid.—Lastly, it may in some cases be desirable to ascertain the quantity of carbonic acid contained in a sample of aërated water, and the pressure which it exerts upon the inner surface of the bottle. This pressure may easily be ascertained by screwing through the cork of the bottle a pressure gauge, such as is frequently used in the case of champagne with a view to prevent the bursting of the bottles.

For the determination of the carbonic acid, the cork of the bottle is to be perforated with a screw tap; this is attached by means of an india-rubber tube to a small flask with a doubly perforated cork through which two glass tubes pass bent at right angles. The second glass tube is connected with a tube filled with chloride of calcium; this in its turn stands in communication with two tubes which are filled with soda-lime. These two latter are weighed before the experiment is commenced. The screw tap is now very gradually opened, and the carbonic acid is allowed to escape. The gas is dried by the chloride of calcium, and is then absorbed in the soda-lime tubes. When no more bubbles escape from the water, the bottle is gently heated in a water-bath, whereby an additional quantity of carbonic acid is obtained. The cork of the bottle is then loosened, and air is sucked through the apparatus to remove the carbonic acid which fills the flask and tubes. The cork is now removed, and an ammoniacal solution of chloride of calcium is added to the water contained in the bottle, which is again corked and allowed to remain at rest for some days. The soda-lime tubes are next weighed, their increase of weight giving the quantity of carbonic acid which has been absorbed.

The ammoniacal solution of chloride of calcium throws down the carbonic acid still remaining dissolved in the water, as carbonate of lime, which is to be collected, dried, weighed, and the carbonic acid calculated from it. The additional quantity of carbonic acid thus obtained is to be added to that contained in the soda-lime tubes.

CHAPTER XLIII.

MALT BEVERAGES AND THEIR ADULTERATIONS

DEFINITION OF ADULTERATION.

Any other substances than the constituents of malt and their derivatives, hops and water in such proportion as in the case of stout, strong and pale ale, to reduce the absolute alcohol to less than 4·5 per cent. and in porter and beer to under 3·5 per cent. Although the law allows the addition of both sugar and salt, we regard these additions as adulterations.

Malt beverages should consist solely of the produce of malt and hops, the former of which has been subject to fermentation. And all the varieties of these beverages should be due to these alone.

The colour should be due solely to the degree of heat to which the malt has been subjected in the kiln, and to the ripeness and colour of the hops employed. Thus for *bitter beer* the palest malt and hops only should be used; for *porter* and *stout* the reverse is the case. The malt should be briskly dried, until the flower of the grain is of a light brown colour, and crushes with a crisp friability between the teeth; the hops, also, should have hung in the autumn sun till they have attained a rich golden hue, and the seeds are perfectly developed. With all attention to these requirements, however, many kinds of beer brewed would still be far from possessing the necessary colour and flavour, and to attain these the maltster is compelled to prepare malt in a peculiar manner, and to make use of *brown* or *black* malt. It must be remembered, nevertheless, that the strength of the porter is due almost entirely to the pale malt, as the other kinds have their saccharine properties so altered by roasting as to render them nearly useless, except for colour and flavour, as before mentioned.

In addition to the distinctive colour of porter and stout, there is one other requisite of still greater importance—namely, the peculiarity of the fermentation. Up to the commencement of the last stage of the process of brewing, the manufacture of porter is conducted in exactly the same manner as that of ale, with the addition of the different flavouring and colouring malts before mentioned; but during the fermentation the great change is effected, all the sugar being converted into spirit, excepting only such portion as is required to preserve the beer from the acetous fermentation, and which is less than in ale, by reason of the larger amount of hops used in proportion to the strength of the wort. The difference will be best appreciated by the following figures. Good porter should weigh about twenty-two pounds specific gravity above water per barrel of thirty-six gallons before the fermentation, and single X ale about the same; but after fermentation, the porter will be found to retain only five pounds weight per barrel, while the ale has seven. Thus, ordinary ale is more liable to derange the stomach, by reason of its greater sweetness, while porter is more heady in proportion to its strength, and soporific in its tendency, from the greater proportion of hops used.

It will be proper to make a few remarks, as succinct as possible, upon the preparation of malt and hops before they come into the brewer's hands; and upon isinglass, the only substance which should be used for fining beer. It may be well to observe, before doing this, that sugar is permitted by law to be used for brewing, and has been and will be consumed extensively whenever malt rises to a sufficiently high price to render it profitable: nevertheless it is advisedly the dogma that 'porter and stout (and indeed all malt liquors) should be brewed of malt and hops only,' as was enunciated in the commencement of this article; for beer brewed from sugar has greater tendency to the acetous fermentation than that prepared from malt.

MALT.

Malt is barley in which germination has been carried on to a certain extent and then suddenly cut off by the application of heat. The process of malting is conducted as follows:—The barley is steeped in a cistern of water for two or three days till well swollen; the liquor is then drawn off, the barley left to drain for five or six hours, after which it is distributed in layers on the slate floors of the malt-house; it now becomes spontaneously very warm and quickly germinates. As soon as the radicle has made its appearance the barley is spread out in a thinner layer in order to stop the germination, and is turned over for two days, it is then made up into a heap until it again becomes heated, which happens usually in about a day. The germination is known to be complete when what is called the acrospire has reached three parts of the way up the grain, particularly observable by a thickening in the back of the grains of barley, when the grain, taken between the thumb and fingers and pressed, discharges its contents in the form of flour, and when it becomes so soft that it is easily pierced by a needle. During this stage the malt emits a smell resembling that of cucumber. The duration of germination in England is about fourteen days, but in Scotland from eighteen to twenty-one days are required, owing to the lower temperature of the couch. When the grain has arrived at this condition, it is thrown into the kiln in a layer of

from three to five inches in thickness, according to circumstances, and while there it is turned over once or twice in about twenty-four hours. The kiln has a wire-gauze bottom, through which the heated air from a furnace of Welsh coal ascends. The briskness of the fire and the time of drying depend upon the colour required in the malt. The process is then complete, with the exception of screening away the 'malt dust'—the dried roots of the embryo plant, a very nutritious food for cattle, but which also does duty sometimes for ground coffee, Scotch snuff, and other articles.

In the choice of malt, the brewer is guided by the growth of the acrospire, as, if it be not sufficiently developed, there is less saccharine matter in the grain than is requisite, and more gluten; and, if overgrown, the saccharine matter is absorbed in the progress of germination.

Malt contains, besides saccharine matter, a substance called diastase, which, in the mash tun, by the action of hot water and agitation by machinery, converts the greater portion of the starch into sugar.

The *pale malt* thus manufactured is the base and strength of all malt liquors. It now remains to notice the other malts used for the purpose of flavouring and colouring stout and porter.

Amber malt, used in the proportion to pale malt of one-eighth part, differs merely in being dried at last faster than the ordinary kind, and by a hotter fire. The delicacy of the flavour of stout is much dependent upon this malt.

Brown or black malt is of a darker colour externally, but internally it is of a deep brown colour. It is manufactured by being placed in the kiln in a layer of only one inch in thickness, and dried by a fierce fire of wood in a very short space of time. This malt, used in the proportion of one-half of the pale malt, is the source of the rich empyreumatic flavour of stout and porter, and does much towards its colour; but this is finally completed by what is called *patent malt*, which is of a very dark brown colour. This malt is pale malt, perfected in the kiln in the ordinary way, and roasted in a similar manner to coffee, only on a much greater scale. The colour of porter, as before mentioned, is principally due to this malt; but it is so powerful an agent, that not more than one-fiftieth part of it is used in proportion to the other malts.

Pale malt is made at a temperature not exceeding from 32° to 38° C.; amber malt at from 49° to 52° C.; brown malt from 65° to 76° C. Patent or black malt at a temperature from 182° to 200° C.

During germination part of the nitrogenous matter of the grain passes into the state of diastase, in which it acts as a ferment, causing a part of the starch to be converted into dextrin and sugar. A further portion of the starch is converted during the kiln drying, while, lastly, in the mash tun the last portion of the starch is transformed into dextrin and glucose.

It has been found that the diastase of the malt is capable of converting a much larger quantity of starch into sugar than that contained in the malt itself, and hence in the making of beer the malt is, in some countries, mixed with unmalted barley and other grain. It is said that in Belgium beer is prepared from malt mixed with potato starch.

Diastase.—This is the substance to which malt owes its property of converting starch into dextrin. It does not exist in all parts of the grain, and is usually most abundant near the plumule. It is not found in the grain before germination. It is a white substance, insoluble in absolute alcohol, but soluble in dilute alcohol and water. Its aqueous solution is neutral to test paper, and is not precipitated by basic acetate of lead. When placed in a solution of boiled starch at 70° C. it quickly decomposes that substance, and converts it first into dextrin and then into glucose. At a boiling temperature this decomposition is instantaneous. One part of diastase, according to Payen and Persoz, is capable of converting 2,000 parts of starch. A solution of diastase quickly becomes acid, and it then loses its power. Its action on starch is destroyed by most of the stronger acids, and even by tartaric and citric acid, but only slightly by acetic acid. It is also prevented by caustic potash, soda, or lime, and in a less degree by magnesia, ammonia, and the alkaline carbonates. According to Bouchardat alcohol and ether exert no influence.

Preparation of Diastase.—The malt is treated with water at from 25° to 30° C.; the solution is heated to 70° C. in order to coagulate the albuminous substances, and the diastase is precipitated by absolute alcohol. It is purified by redissolving and reprecipitating it. The proportion of diastase in malt is stated not to exceed 0·002 to 0·003 per cent.

Maltose is the name given by Dubrunfaut to the sugar produced by the action of the diastase on malt starch. It resembles dextroglucose in its crystalline form, but its dextrorotatory power is three times as great. It is converted into dextroglucose by boiling with dilute sulphuric acid.

The *cellulose* in malt is almost entirely destroyed. The presence of cellulose in the raw grain, and its comparative absence in malt may be readily shown by tearing into pieces with needles sections of the grain, and washing away the starch.

It will be seen under the microscope that malt still contains a considerable quantity of starch, there being a great many granules visible which do not appear to have undergone any alteration in form or substance. Only about one-half of the starch, it is said, is converted into sugar during malting.

The barley during malting absorbs oxygen and emits carbonic acid. The grain loses from 1·5 to 3 per cent. of its weight; the gluten and mucilage to a great degree disappear; the colour becomes whiter, and the substance of the barley so brittle that it readily crumbles.

The bulk of good malt exceeds that of the barley from which it is obtained by about 8 or 9 per cent.

HOPS.

Hops consist of the female flowers or catkins of a diœceous plant, *Humulus Lupulus*, belonging to the natural order *Urticaceæ*. English hops are chiefly grown in the counties of Kent, Sussex, and Surrey; but also in Nottingham and Worcestershire.

Hops are a very delicate and precarious crop, affected greatly by the weather, and they also fall a prey to various kinds of blight, of which the most devastating are the *fly*, and *mould* or *rust*. The former is the well-known green insect and black fly that attacks the rose plants; and its ravages are so great that three-fourths of the year's crops are sometimes sacrificed. The latter is a fungus which attacks the hop itself, and not only prevents its proper development and thus destroys its preservative properties, but also communicates an unpleasant flavour to the beer.

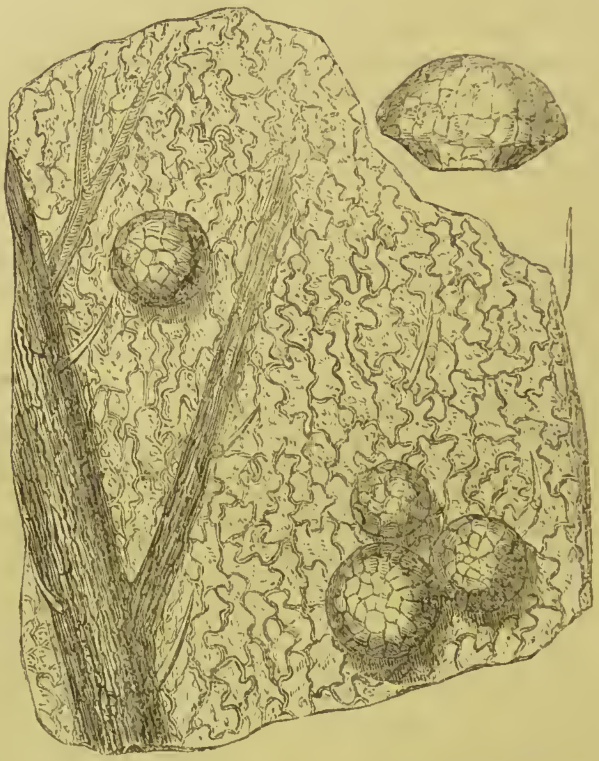
Like the vine, the hop loves the sun, and can scarcely have too much of it; it also resembles that plant in the soils and situations it most prefers—the sunny sides of sloping hills, and the well-cultivated soil of Kent, resting on the Kentish rag or ironstone. The most choice hops are grown in East Kent, and those next in estimation in Mid-Kent. In ordinary seasons, the hops grown in Kent nearly suffice for all the malt liquors brewed in England; but in seasons of scarcity foreign hops are much used. Hitherto, the hops grown in Belgium have been considered the best, and, in appearance, there is no doubt they are so, as the Belgian growers have taken great pains to imitate our mode of preparation and packing; but the Bavarian hops are really much finer in quality and flavour, and the aroma is more perfectly preserved by their method of preparation, which differs from ours.

Some few hops are imported from America, but though very powerful, they are so rank and peculiar in flavour that, without great improvement in cultivation, they are never likely to be extensively used.

The preparation of hops is a very simple process, and may be described in few words. The poles, with the hop plants still hanging on them, are pulled from the ground, when the hops are picked, principally by women and children, to a great number of whom it affords temporary employment; they are then dried on a kiln, somewhat resembling the malt kiln, but the heat is much less, and should not exceed 50° C., the test of their being sufficiently dried being the snapping of the flower-stalk; the floor of the kiln is made of hair-cloth. A small portion of sulphur is burned on the kiln fire, for the purpose, partly, of preserving the hops—at least this is the plea, and there may be some truth in it, as the sulphur may destroy any insect or fungus remaining in the hops—but the great reason for the use of sulphur is its bleaching property, which renders the hops more sightly to the eye. After they have been thus dried and bleached they are packed tightly into the bags, or pockets, as they are called, to exclude the air. They are packed so tightly by the hydraulic press that they become sufficiently solid to be cut in blocks with a knife.

All English hops are prepared in this manner, and the Belgians, finding that the bleaching and packing have a great effect upon the eye, have followed our example; but the Bavarian growers still adhere to the custom of their ancestors, and it is to be hoped they will continue to do so, with increased attention to cultivation and packing, which will render their hops equal to the best English produce.

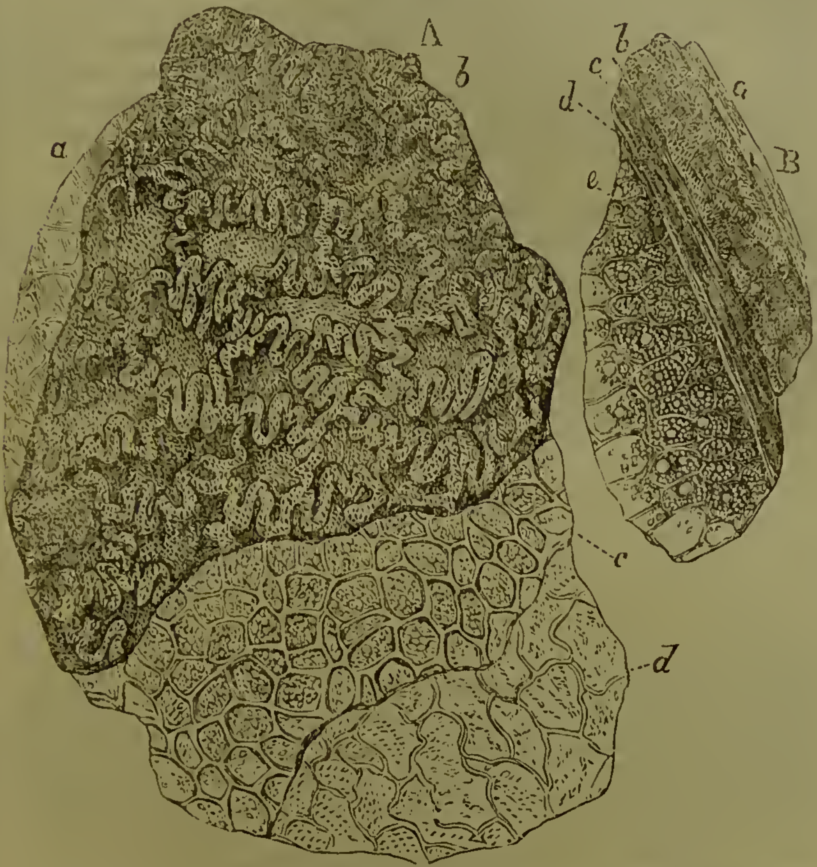
Fig. 205.



Portion of *leaf* and *glands* of HOP. Magnified 100 diameters.

The mode in use in Bavaria is as follows:—When the hops are ripe the plant is cut off close to the ground, and the hops are left on the poles to dry in the sun. This method preserves the aroma entirely, and all the essential oil; the consequence is that, although they are packed loosely in bales and look like withered leaves, they have more strength and flavour in proportion to their quality than the English hops. It is somewhat premature to speak of this method as regards the preservation of the hops compared with that followed in England, as the Bavarian hops are a recent importation; in our variable climate the process by which they are dried would be unsuitable; but this at least may be deduced from the comparison, that great care should be

Fig. 206.



Seed of Hop. A. *Testa*, showing the four coats of which it is formed, the second, marked *b*, being the most characteristic. B. *Vertical section of seed*, exhibiting the four membranes, and the substance of the seed, *e*. Magnified 200 diameters.

taken in the use of the sulphur that the flavour is not affected; and also that a very low degree of heat is advisable, as there is no doubt much of the essential oil flies off in the drying process.

Hops prepared in the English manner frequently become brown and musty by keeping. In such a condition they are wholly unsaleable; but often so great is the demand for hops that the most worthless descriptions of foreign hops are purchased, and subjected to fumigation—by which means their colour is restored, and their property of checking fermentation revived. To effect this, as much as 10 lbs. of sulphur are employed in some cases for every hundredweight of hops. As large a quantity as 1·0 per cent. of free sulphuric acid has been met with in samples of bleached hops; this acid is formed by the oxidation of the sulphurous acid generated during the bleaching process.

The catkins consist of scales, of a pale yellow colour when ripe, at the base of which are small rounded seeds of a reddish colour. They are imbedded in a yellow powder, which is the most valuable part of the hop. The hop should not be gathered until the seed is well ripened. When rubbed hops should have a resinous feeling, with an aromatic odour. They should not present any green specks, nor should there be any appearance of a fungus on the stem of the flower.

Payen and Chevallier's analysis of hops is as follows:—

Volatile oil	2·00
Lupulin	10·30
Resin	55·00
Lignin	32·00
Loss	0·70
	100·00

With traces of fatty, astringent and gummy matters, and malic acid.

The yellow lupulinic grains, which used formerly to be called farina or pollen, but which really consist of crude lupulin, are said in good samples to amount to one-sixth of the weight of the hops. According to Dr. Ives this powder has the following composition:—

Tannin	4·16
Extractive	8·33
Bitter principle	9·16
Wax	10·00
Resin	30·00
Lignin	38·33
	99·98

Messrs. Payen, Chevallier and Pelletan give the composition of the lupulinic grains as follows:—

Volatile oil	2·00
Lupulin	10·30
Resin	55·00
Lignin	32·00
Loss	0·70
	100·00

The substance ordinarily called lupulin, but which is in fact a mixture of lupulin with a variety of other substances, when distilled with water, yields *valerianic acid,* and a *volatile* oil containing a *hydrocarbon,* together with *valerol.*

The resinous matter which remains after the distillation still contains valerol, and, when distilled with slaked lime, yields *valeraldehyde.*

According to R. Wagner, the *volatile oil* consists of a mixture of a hydrocarbon, isomeric with oil of turpentine, and a substance, apparently identical with valerol, which may be oxidised into valerianic acid, and hence hops acquire, by keeping, the odour of cheese.

According to Person, lupulin distilled with water yields valerianic acid and an oil lighter than water, at first neutral, but after a while becoming acid and resinous; it begins to boil at 140° C., but the boiling point gradually rises to 300° C.

Heated with alcohol, lupulin yields about 65 per cent. of its weight, consisting of resin, extractive matter and tannin—the two latter soluble in water, whereas the resin, which forms about 62 per cent. of the lupulin, is insoluble.

The bitter principle of the hop, *lupulite* or *true lupulin,* amounts, according to Payen and Chevallier, to between 8·3 and 12·5 per cent. of the crude lupulin, and, according to Ives, to about 10 per cent. It is dissolved out, together with malic acid, by digestion of the crude lupulin in water. To separate it, the malic acid is neutralised with chalk, the liquid evaporated to dryness, and the residue treated with ether, whereby a small quantity of resin is removed. The lupulite is next separated from the malate of calcium by means of alcohol, when, on the evaporation of the alcoholic extract, it is obtained in a pure state.

When heated, lupulin emits the characteristic smell and possesses the peculiar bitterness of hops. It is soluble to the extent of 5 per cent. in water, and, while it is quite soluble in alcohol, it is only slightly so in ether.

The presence of the tannin in the hops is supposed to be important, it aiding the precipitation of the nitrogenous matter of the malt, and so assisting the clarification of the beer.

According to A. Wagner, the tannin amounts to between 3·5 and 5·7 per cent. of the hops.

The following analyses of the ash of hops have been made:—

	Way and Ogston.			H. Watts.
	Bentley variety.	Golding variety.	Grape variety.	Grape variety.
Potash	11·98	24·88	25·56	19·41
Soda	—	—	—	0·70
Lime	17·93	21·59	18·47	14·15
Magnesia	5·94	4·69	5·27	5·34
Alumina	—	—	—	1·18
Oxide of iron	1·86	1·75	1·41	2·71
Sulphuric acid	7·01	7·27	11·68	8·28
Chlorine	—	—	—	2·26
Silica	22·97	19·71	9·99	17·88
Carbonic acid	5·44	2·17	4·54	11·01
Phosphoric acid	21·38	14·47	17·58	14·64
Chloride of potassium	5·45	—	4·34	—
Chloride of sodium	—	3·42	0·12	—
Charcoal and loss	—	—	—	2·44
	99·96	99·95	98·96	100·00
Ash per cent. of dry substance	8·07	5·95	7·21	
Ash per cent. of fresh substance	7·27	5·22	6·52	6·5

Properties of hops.—The volatile oil contained in the hops possesses marked narcotic properties. Hence a pillow of the catkins has often been prescribed to promote sleep in cases where the administration of opium would be objectionable.

The infusion of hops is an aromatic tonic, and it sometimes acts as a diuretic and sudorific.

'The lupulinic grains are also aromatic and tonic, and are soothing, tranquillising, and slightly sedative. Hops have been administered internally to relieve restlessness consequent upon exhaustion or fatigue, to induce sleep in the wakefulness of mania and other maladies, to calm nervous irritation, and to relieve pain in gout and rheumatism. They have also been applied topically in the form of a fomentation or poultice, as a resolvent or discutient in painful swellings or tumours.' —*Pereira.*

FININGS.

We may now add a few words upon brewers' finings. These consist chiefly of isinglass or sometimes gelatin. The isinglass used by brewers is the cartilage of the sturgeon and other fish. The brewer buys his isinglass as imported, in rough pieces, as also the dressings and pickings rejected in the preparation of the finer sorts of isinglass for the confectioner, &c. The 'finings' for porter are thus prepared:—The isinglass is put into some sour beer to dissolve, technically to cut, which takes place in different times, according to the kind of isinglass made use of. Sometimes white of egg, serum of blood, and even Carrageen moss are employed as finings for beer.

THE BREWING OF BEER.

Preparation of the wort.—In order to make the wort the malt is crushed, and placed in a tun having a false bottom, when water of a temperature of about 82° C. is poured over it, and the whole well stirred. The mixture is left to stand for a few hours to clarify, when it is transferred to a copper in which it is boiled with the hops. After being sufficiently boiled it is drawn off into large shallow wooden vessels termed coolers; from these it is conveyed to the fermenting vats, which in some cases are of large capacity, and in these it is mixed with yeast, obtained from a previous brewing.

Fermentation of the wort.—Soon the whole liquid becomes in a state of agitation, much of the sugar is converted into alcohol and carbonic acid, a great part of the latter escaping as gas; during the fermentation the quantity of yeast is greatly multiplied, it feeding upon the nitrogenous matter of the malt, the new yeast thus aiding that first added in the transformation of the sugar. Gradually, as the fermentation proceeds, the yeast forms a thick frothy layer on the surface of the liquid, and is skimmed off.

The fermentation is, of course, not permitted to be complete, but is stopped at a certain point by the removal of the yeast and by drawing off the beer into casks, in which, however, a slow fermentation continues to take place, a further portion of the sugar being converted into alcohol, and the beer thus becoming stronger and less sweet. While in the casks the beer becomes clear and bright, an additional quantity of yeast collects on the surface, and is thrown off through the bung-holes. Sometimes, however, it is necessary, when the beer does not become sufficiently clear and bright, to employ finings.

There is, of course, great variety in the physical characters and quality of the malt beverages manufactured in this country. They may be divided into the *weak* and the *strong*, according to the amount of alcohol which they contain; into the *sweet* and the *dry* in accordance with the amount of saccharine matter which they have been allowed to retain. Sweet beers, when bottled, undergo further fermentation, giving rise to a fresh formation of alcohol and carbonic acid, causing those beers to become effervescent when the bottles are uncorked. Then there are the *bitter* beers and the *pale* ales, the *brown* ales and the *black porter* and *stout*.

In the manufacture of bitter beer or pale ale the best and palest malt and hops are used, and great care is taken that the temperature during fermentation should not rise above 22° C. By this means the flavour and aroma of the hops are best preserved, while the tendency to the formation of acetic acid is lessened.

Small beer is of course very weak, and is usually made by extracting with a fresh quantity of water the residue left after the preparation of the first wort.

It has been ascertained that the temperature at which the fermentation of the beer has taken place exerts a great effect on its keeping properties, and on its liability to become sour from the formation of acetic acid. In the beers of England, France, Belgium and North Germany, the fermenting temperature ranges between 18° and 32° C., and the beer so produced, as is known, is liable to become sour; but in Bavaria the temperature ranges between 8° and 10° C., and the beverage thus made is much less prone to acetification.

According to Liebig the explanation of this difference is as follows:—When the wort is fermented at a high temperature, the action of the yeast is very brisk, and the large bubbles of carbonic acid formed carry the yeast globules to the surface of the liquid, where it forms a thick scum. The fermentation in this case is called *top fermentation*. This scum prevents the access of the oxygen of the air to the fermenting fluid, and the yeast takes therefore the oxygen necessary for its formation from the sugar contained in the liquid; the sugar is thus destroyed before the whole of the nitrogenous matter held in solution has been used up by the yeast. The beer, after it has been drawn off, contains therefore, in the case of top fermentation, nitrogenous matter which, acting as a ferment, induces the oxidation of the alcohol and the formation of acetic acid.

When, on the other hand, the wort is fermented at a low temperature, as is the case in the preparation of the Bavarian beer, the carbonic acid escapes from the liquid in minute bubbles, and the yeast is not carried to the top, but remains at the bottom. Hence this mode of fermentation is called *bottom fermentation*. The oxygen of the air has free access to the liquid, and consequently the yeast takes the necessary oxygen from the air, instead of the sugar as in the previous case, and the nitrogenous matter is wholly converted into yeast before all the sugar has been decomposed.

The beer thus prepared contains therefore but little nitrogenous matter which might act as a ferment, and it keeps consequently much better than beer prepared by top fermentation. In the latter case the yeast consists of 'gluten oxidised in a state of putrefaction, and the bottom yeast is the gluten oxidised by slow combustion.'—*Watts.*

Quality of the water used.—It is well known that the quality of the water used has a great effect on beer, on the extraction of the soluble constituents of the malt, and on the subsequent clarification of the fermented beverage.

For the first purpose a soft or even an alkaline water would appear to be the most suitable, but for the second there is no doubt that waters containing much lime are the best. The lime combines with the phosphoric acid of the malt and forms an insoluble salt, which assists in carrying down any suspended matter.

In the course of boiling, the excess of carbonic acid in the water, by which the carbonates of lime and magnesia are dissolved, is expelled, and these salts are precipitated; again, the alkaline phosphates present in malt have the power of decomposing and precipitating sulphate of lime, phosphate of lime and a soluble alkaline sulphate being formed, but part of the phosphate of lime so formed is redissolved in the acid generated during fermentation. The water from being at first hard thus becomes comparatively soft, and in this state is well suited for the extraction of the active properties of the malt and hops.

The waters used by most of the brewers at Burton-on-Trent contain a large quantity of *sulphate of lime*, and it is to this constituent that the superiority of this water in the brewing of pale ale has been attributed.

The following is an analysis of the water used in the brewery of Messrs. Allsopp & Co., by Dr. Henry Böttinger:—

	Grains per Gallon.
Chloride of sodium	10·12
Sulphate of zinc	7·65
Sulphate of lime	18·96
Sulphate of magnesia	9·95
Carbonate of lime	15·51
Carbonate of magnesia	1·70
Carbonate of iron	0·60
Silica	0·79
Total solids	65·28

The water is remarkable for its complete freedom from organic matter.

The composition of the water used by Messrs. Bass & Co., according to Cooper, is as follows:—

	Grains per Gallon.
Carbonate of lime	9·93
Sulphate of lime	54·40
Chloride of calcium	13·28
Sulphate of magnesia	0·83
Total	78·44

With the above analyses of the water used by Messrs. Allsopp and Bass, it will be interesting to contrast the mineral constituents in the ash of the beer of those brewers.

Mineral Matter contained in one Imperial Gallon.

	Allsopp.	Bass.
Alkaline sulphates, chiefly of potash	78	62
Alkaline chlorides	28	25
Alkaline carbonates and phosphates	14	19
Phosphate of lime and magnesia	102	91
Total	222	197

These two last analyses include, of course, not merely some of the saline constituents of the water used in making the beers, but also those of the malt and hops employed, notably the phosphates of the malt.

It will be observed that the earthy salts, the carbonates and sulphates of lime and magnesia, which impart the quality of hardness to water, have disappeared, and that the Burton water, though hard at first, really becomes a soft water, as contained in the beer.

But the chemical constitution of the Burton water explains also another circumstance connected with Burton ales. It is known that these ales speedily become bright and clear, that they never require finings to be employed, and are fit for use almost as soon as brewed.

Now the depurating power of lime is well known, so that it has long been employed in the clarification of cane and other vegetable juices. But in the case of Burton water the action is probably purely mechanical, it carrying down in its precipitation suspended impurities, thus rendering the beer transparent and bright.

We give in the following table some analyses made by ourselves of the composition of the beer of Messrs. Allsopp & Co. and Messrs. Bass & Co.:—

Grains per gallon.

	Messrs. Allsopp & Co.		Messrs. Bass & Co.	
	For exportation to India.	For exportation.	For home consumption.	
Sugar . .	200	320	390	420
Gum . .	2,080	2,110	3,930	2,660
Bitter extract .	810	750	760	800
Total solids .	3,090	3,180	5,080	3.880
Alcohol . .	3,540	3,820	3,983	3,744
Water . .	63,370	63,000	60,937	62,376
	70,000	70,000	70,000	70,000

THE ANALYSIS OF BEER.

The usual determinations in making an analysis of genuine beer are the following:—The *specific gravity, acidity, sugar, bitter extractive, total solids, mineral matter, salt, alcohol,* and *carbonic acid.*

Before the *specific gravity* of the beer can be taken, it is necessary that it should be freed from carbonic acid. This object is usually effected by well shaking the beer in a corked bottle for ten minutes or more, taking out the cork from time to time to allow of the escape of the gas, and sucking air through the bottle by means of a glass tube. The gravity may then be taken, either by the areometer or more correctly by the specific gravity bottle, after the beer has been cooled down to 15·5° C.

In the beer, freed from carbonic acid in the manner described, the acidity is determined by the standard soda solution which has been so often referred to already, the amount of alkali used being calculated into acetic acid.

For the determination of the *sugar*, a convenient quantity of the beer, say 200 cc., should be diluted with 10 volumes of water, and the sugar should then be estimated by means of the copper test in the manner fully described in the article on ‘Sugar.’

Another portion of the beer, say 10 cc., should be measured into a flask, diluted with water, and boiled for two hours with two drops of sulphuric acid, until all the *dextrin* and *gum* has been converted into glucose, when the acid is neutralised, and the liquid made up to 100 cc. The sugar is to be estimated in the usual manner, the difference between the two estimations giving the amount of glucose, which is to be calculated into dextrin. Or a portion of the beer may be evaporated to the consistence of a thin syrup, strong alcohol being then added as long as any dextrin is precipitated; for its purification the dextrin is to be redissolved in water and again precipitated, dried and weighed.

The sugar is sometimes estimated by evaporation and drying from the alcoholic solution, but in the case of beers containing much hop, this would be a fallacious mode of proceeding, as the alcoholic extract would contain lupulin and other matters soluble in the spirit.

The bitter extractive.—Evaporate to dryness 50 cc. of the beer, and extract with repeated additions of cold absolute alcohol. This dissolves the *lupulin* and other matters soluble in alcohol. The solution is evaporated and the extractive matter weighed.

The total solids.—10 cc. of the beer are to be evaporated on the water-bath in a weighed platinum basin, or better still, in a current of dry air. After all moisture has been driven off, as shown by the weight becoming constant, the amount of *solids* is thus arrived at.

This is the usual method whereby the solids contained in beer are estimated. It is an object of greater importance to the brewer to know the amount of sugar, as deduced from the specific gravity of the original wort, than the quantity of total solids contained in the beer. From the amount of alcohol contained in the fermented beverage the quantity of sugar from which it has been produced can easily be calculated—198 parts of glucose yielding 100 parts of alcohol. This amount of sugar added to that contained in the beer approximately gives the total amount of sugar originally present in the wort.

To effect this determination, the brewer has only to evaporate a given quantity of the beer to at least one-half, and to fill up with water to the original bulk. The difference in the specific gravities before and after boiling gives by simple calculation the amount of alcohol contained in the beer, and which is shown by reference to tables which have been specially constructed. The amount of alcohol being thus ascertained, its equivalent in sugar is next determined, and this is then added to the sugar contained in the dealcoholised beer.

Specific Gravity and Strength of Malt Extract.

Specific gravity.	Malt extract in 100 parts of liquid.	Specific gravity.	Malt extract in 100 parts of liquid.	Specific gravity.	Malt extract in 100 parts of liquid.
1·000	0·000	1·024	6·000	1·048	11·809
1·001	0·250	1·025	6·244	1·049	12·047
1·002	0·500	1·026	6·488	1·050	12·285
1·003	0·750	1·027	6·731	1·051	12·523
1·004	1·000	1·028	6·975	1·052	12·761
1·005	1·250	1·029	7·219	1·053	13·000
1·006	1·500	1·030	7·463	1·054	13·238
1·007	1·750	1·031	7·706	1·055	13·476
1·008	2·000	1·032	7·950	1·056	13·714
1·009	2·250	1·033	8·195	1·057	13·952
1·010	2·500	1·034	8·438	1·058	14·190
1·011	2·750	1·035	8·681	1·059	14·428
1·012	3·000	1·036	8·925	1·060	14·966
1·013	3·250	1·037	9·170	1·061	14·904
1·014	3·500	1·038	9·413	1·062	15·139
1·015	3·750	1·039	9·657	1·063	15·371
1·016	4·000	1·040	9·901	1·064	15·604
1·017	4·250	1·041	10·142	1·065	15·837
1·018	4·500	1·042	10·381	1·066	16·070
1·019	4·750	1·043	10·619	1·067	16·302
1·020	5·000	1·044	10·857	1·068	16·534
1·021	5·250	1·045	11·095	1·069	16·767
1·022	5·500	1·046	11·333	1·070	17·000
1·023	5·750	1·047	11·595		

The less extractive matter a beer contains, the more accurate are the results thus obtained, but if a beer be very rich in extractive matter, the results are only approximate, and cannot be relied upon. Hence this method is not now deemed sufficiently accurate even for the practical purposes of the brewer. But another method, which we shall shortly describe, has been devised, giving results of greater, but still by no means absolute accuracy.

Attending the conversion of the sugar into alcohol there is of course a very considerable diminution in the specific gravity of the liquid, the gravity of the wort being always much greater than that of the beer itself.

Now since the brewer is allowed what is called a 'drawback' on all beer exported, and this allowance is founded upon the *original* gravity of the wort, it is necessary that the Excise officer should be possessed of a method whereby he can determine the gravity of the wort before fermentation.

We have already referred to one method whereby this object is in a measure effected, namely, by calculating all the extractive matter contained in beer as sugar, and adding to it an amount of sugar corresponding to the alcohol contained in the beer; but the extractive matters of even genuine malt beer are compounded of several substances besides starch sugar, as gum, dextrin, extractive matters of the hop, undefined extractive matters of the malt, glycerin, colouring matter, mineral matter, and in the case of the darker beers, and especially of porter and stout, a considerable amount of caramel. In cases in which starch sugar and cane sugar are directly added to the wort, as is now permitted, the causes of variation are still further augmented. Hence it is obviously an incorrect method of proceeding to base the calculation on the supposition that the whole of these matters comport themselves exactly as does sugar, and are all convertible into alcohol.

To meet this objection, Messrs. Graham, Hofmann, and Redwood have made certain observations and experiments based upon worts of different gravities and of known composition. They find that the specific gravities of solutions of starch sugar, cane sugar, dextrin, extractive substance, caramel, pale and brown malt, which contain equal quantities of carbon, all vary, the variation in each case being in the direction of producing a less specific gravity of the wort than a solution of starch sugar only. Hence, had the solid contents still remaining in the beer all been estimated as cane sugar, the gravity would have been too high, and on the other hand it would appear that part of the starch sugar is capable of being converted into an 'unfermentable extractive matter,' which gives a solution of lower specific gravity for the same amount of carbon, and hence the estimate of the original gravity would come out too low; indeed, it is affirmed that this extractive substance indicates only about five-sixths of the saccharine principle from which it is derived.

The experiments upon solutions of known composition by Messrs. Graham, Hofmann, and Redwood consisted in fermenting these solutions and analysing them in different stages of fermentation. They estimated the specific gravity of the fermented liquid, and distilled a measured quantity of it, took the specific gravity of the distillate after it had been made up to its original bulk by the addition of water, and they likewise estimated the specific gravity of the residue in the retort or dealcoholised liquid, which also had been made up to its original bulk. The difference between the specific gravity of the distillate and the specific gravity of water they called the 'spirit indication' of the beer, whilst the difference between the original gravity of the wort and of the dealcoholised liquid they called 'gravity lost.'

The spirit indication and the gravity lost both may be calculated for sugar, but it is obvious that they cannot exactly furnish the same results. For while the spirit indication is based upon the specific gravity of the spirit, which may of course be accurately calculated into sugar, the 'gravity lost' is obtained from a liquid of unknown composition, the gravity of which, as we have seen above, is lower than the gravity of an equally strong solution of starch sugar. To make the results obtained in the latter way correspond with those given by the former method, a larger number is to be added to the specific gravity of the fermented liquid to obtain the gravity of the original wort, than to the results obtained in the former method. This difference is obvious by a reference to the annexed tables by Messrs. Graham, Hofmann, and Redwood, copied from 'Watts's Dictionary.'

Table to ascertain Original Gravities by the Distillation Process.

Degrees of Spirit Indication, with corresponding Degrees of Gravity lost in Malt Worts.

Degrees of spirit indication.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	—	0·2	0·6	0·9	1·2	1·5	1·8	2·1	2·4	2·7
1	3·0	3·3	3·7	4·1	4·4	4·8	5·1	5·5	5·9	6·2
2	6·6	7·0	7·4	7·8	8·2	8·6	9·0	9·4	9·8	10·2
3	10·7	11·1	10·5	12·0	12·4	12·9	13·3	13·8	14·2	14·7
4	15·1	15·5	16·0	16·4	16·8	17·3	17·7	18·2	18·6	19·1
5	19·5	19·9	20·4	20·9	21·3	21·8	22·2	22·7	23·1	23·6
6	24·1	24·6	25·0	25·5	26·0	26·4	26·0	27·4	27·8	28·3
7	28·8	29·2	29·7	30·2	30·7	31·2	31·7	32·2	32·7	33·2
8	33·7	34·3	34·8	35·4	35·9	36·5	37·0	37·5	38·0	38·6
9	39·1	39·7	40·2	40·7	41·2	41·7	42·2	42·7	43·2	43·7
10	44·2	44·7	45·1	45·6	46·0	46·5	47·0	47·5	48·0	48·5
11	49·0	49·6	50·1	50·6	51·2	51·7	52·2	52·7	53·3	53·8
12	54·3	54·9	55·4	55·9	56·4	56·9	57·4	57·9	58·4	58·9
13	59·4	60·0	60·5	61·1	61·6	62·2	62·7	63·3	63·8	64·3
14	64·8	65·4	65·9	66·5	67·1	67·6	68·2	68·7	69·3	69·9
15	76·5	—	—	—	—	—	—	—	—	—

Table to ascertain Original Gravities by the Evaporation Process.

Degrees of Spirit Indication, with corresponding Degrees of Gravity lost in Malt Worts.

Degrees of spirit indication.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	—	0·3	0·7	1·0	1·4	1·7	2·1	2·4	2·8	3·1
1	3·5	3·8	4·2	4·6	5·0	5·4	5·8	6·2	6·6	7·0
2	7·4	7·8	8 2	8·7	9·1	9·5	9·9	10·3	10·7	11·1
3	11·5	11·2	12·4	12·8	13·2	13·6	14·0	14·4	14·8	15·3
4	15·8	16·2	16.6	17·0	17·4	17·9	18·4	18·8	19·3	19·8
5	20·3	20·7	21·2	21·6	22·1	22·5	23·0	23·4	23·9	24·3
6	24·8	25·2	25·6	26·1	26·6	27·0	27·5	28·0	28·5	29·0
7	29·5	30·0	30·4	30·9	31·6	31·8	32·3	32·8	33·3	33·8
8	34·3	34·9	35·5	36·0	36·6	37·1	37·7	38·3	38 8	39·4
9	40·0	40·5	41·0	41·5	42·0	42·5	43·0	43·5	44·0	44·4
10	44·9	45·4	46·0	46·5	47·1	47·6	48·2	48·7	49·3	49·8
11	50·3	50·9	51·4	51·9	52·5	53·0	53·5	54·0	54·5	55·0
12	55·6	56·2	56·2	57·3	57·8	58·3	58·9	59·4	59·9	60·5
13	61·0	61·6	62·1	62·7	63·2	63·8	64·3	64·9	65·4	66·0
14	66·5	67·0	67·6	68·1	68·7	69·2	69·8	70·4	70·9	71·1
15	72·0	—	—	—	—	—	—	—	—	—

The first column contains the whole degrees of the spirit indication, while the tenth of the degrees are placed at the top of the other columns. The degrees of gravity lost which are found by going horizontally to the right from the degree of spirit indication lost until the respective column headed by the tenth of the degree is reached, are to be added to the gravity of the fermented liquid to obtain the specific gravity of the original wort.

It seems somewhat strange that Messrs. Graham, Hofmann, and Redwood should not have taken notice of the effect of the extract of the hops upon the specific gravity of the wort.

Mineral matter.—The total solids of the beer, obtained as described, are incinerated at the lowest possible temperature, and the ash weighed.

Salt.—The ash is dissolved in pure nitric acid and the chlorine is precipitated by means of a solution of nitrate of silver, the resulting chloride of silver being washed, dried and weighed.

The chlorine cannot be determined volumetrically in the usual manner, since the phosphates contained in the ash exert a considerable influence upon the quantity of silver solution used.

Alcohol.—100 cc. of the beer are to be neutralised with caustic soda and the alcohol distilled off and estimated from the specific gravity of the distillate, after this has been made up to the volume of the beer employed, as described in the article on 'Wine.' We give below a table of the specific gravity of mixtures containing a small amount of alcohol only:—

Specific Gravity and Strength of Spirits.

Volume per cent.	Weight per cent.	Specific gravity.	Volume per cent.	Weight per cent.	Specific gravity.
1·	0·80	0·99850	3·0	2·40	0·99560
1·1	0·88	0·99835	3·1	2·48	0·99546
1·2	0·96	0·99820	3·2	2·56	0·99532
1·3	1·04	0·99805	3·3	2·64	0·99518
1·4	1·12	0·99790	3·4	2·72	0.99504
1·5	1·20	0·99775	3·5	2·80	0·99490
1·6	1·28	0·99760	3·6	2·88	0·99476
1·7	1·36	0·99745	3·7	2·96	0·99462
1·8	1·44	0·99730	3·8	3·04	0·99448
1·9	1·52	0·99715	3·9	3·12	0·99434
2·0	1·60	0·99700	4·0	3·20	0·99420
2·1	1·68	0·99686	4·1	3·28	0·99406
2·2	1·76	0·99672	4·2	3·36	0·99392
2·3	1·84	0·99658	4·3	3·44	0·99378
2·4	1·92	0·99644	4·4	3·52	0·99364
2·5	2·00	0·99630	4·5	3·60	0·99350
2·6	2·08	0·99616	4·6	3·68	0·99336
2·7	2·16	0·99602	4·7	3·76	0·99322
2·8	2·24	0·99588	4·8	3·84	0·99308
2·9	2·32	0·99574	4·9	3·92	0·99294

Specific Gravity and Strength of Spirits—cont.

Volume per cent.	Weight per cent.	Specific gravity.	Volume per cent.	Weight per cent.	Specific gravity.
5·0	4·00	0·99280	6·6	5·30	0·99072
5·1	4·08	0·99267	6·7	5·38	0·99059
5·2	4·16	0·99254	6·8	5·46	0·99046
5·3	4·24	0·99241	6·9	5·54	0·99033
5·4	4·32	0·99228	7·0	5·62	0·99020
5·5	4·40	0·99215	7·1	5·70	0·99008
5·6	4·48	0·99202	7·2	5·78	0·98996
5·7	4·56	0·99189	7·3	5·86	0·98984
5·8	4·64	0·99176	7·4	5·94	0·98972
5·9	4·72	0·99163	7·5	6·02	0·98960
6·0	4·81	0·99150	7·6	6·11	0·98949
6·1	4·89	0·99137	7·7	6·19	0·98936
6·2	4·97	0·99124	7·8	6·27	0·98924
6·3	5·05	0·99111	7·9	6·35	0·98912
6·4	5·13	0·99098	8·0	6·43	0·98900
6·5	5·21	0·99085	—	—	—

Carbonic acid.—The free carbonic acid is to be determined in the manner at length described in the article on 'Aërated Beverages.' Beer usually contains no more than from 0·1 to 0·5 per cent., even when bottled.

THE ADULTERATIONS OF MALT BEVERAGES.

Genuine malt beverages should consist only of the products of malt, hops, and water, and any addition to these may, strictly speaking, be viewed in the light of an adulteration. Such for ages has been the composition of the malt beverages of this country. Now, however, all this seems to be threatened with a change. The law itself is revolutionising the manufacture of beer, and is legalising the wholesale adulteration of this national beverage.

The addition of cane sugar, treacle, and salt to the wort is now permitted; indeed, we have met with instances in which an article, which had been denominated beer, has been produced without its containing a particle of either malt or hops.

It may be said that since the most important constituent of malt is its sugar, and that it is this which furnishes the alcohol of the beer, no great harm is done by permitting the addition of a further quantity of sugar. But this mode of reasoning is very fallacious, since extract of malt contains a variety of other substances, organic and mineral, besides sugar, so that the beverage produced from pure malt extract and a mixture of this with sugar and various other substances, is very different in its actual composition and in its dietetic properties and effects.

If it be allowable to make so-called beer from other constituents than malt and hops, surely this should be distinguished from the true and genuine malt beverages by the adoption of some distinctive name, so that the public may know what they are really consuming.

The adulterations which either have been or are practised on beer are multifarious, and they include the following:—*Water, sugar* and *treacle, liquorice, burnt sugar, vegetable bitters,* including *picric acid, cocculus indicus* and *strychnia*; *carminatives* and *opium*; various *mineral* adulterations, as those with *alum, salt, sulphate of iron, carbonate of lime, soda,* &c.

The adulteration with water.—The practice of diluting with water nearly all liquid articles of consumption, especially those containing alcohol, is almost universal. This admixture is one of the most frequent adulterations practised upon beer, and it is one which is commonly effected by the publican, who contrives to make by it three barrels of beer out of two, endeavouring to make up for the dilution of the liquid and the consequent loss of its sensible properties by adding sugar, including burnt sugar, to restore the colour, and salt to increase the pungency and flavour.

Adulteration with cane sugar.—Now, although the addition of sugar to the wort, including cane sugar, is allowed by law, we presume such an addition is not permissible to the beer after it is fermented and with a view to its adulteration by means of water; and hence, when the presence of cane sugar is demonstrated in any beer, it must be taken as affording conclusive evidence of adulteration.

Sometimes both cane sugar and glucose are introduced into the beer by making use of treacle and the form of impure sugar termed 'foots.'

Adulteration with liquorice.—*Spanish juice* or *liquorice* is not unfrequently used in the adulteration of porter and stout for the double purpose of colouring and sweetening the beverage.

Adulteration with burnt sugar, caramel, or essentia bina.—When malt is dried at a high temperature and is converted into what is known as black or patent malt, part of the sugar is caramelised, and when the burnt sugar in the beer is derived from this source it is, of course, not to be regarded as an adulteration. But when burnt sugar not so derived is added to cover and conceal the impoverishment of the beer with water, its presence must in that case be regarded in the light of an adulteration.

Adulteration with vegetable bitters.—The vegetable bitters which have been known to be employed in the adulteration of beer are *gentian, chiretta, quassia, wormwood, orange peel, orange powder* and *camomile*—the last two possess aromatic properties, the camomile being likewise narcotic—also *picric acid, cocculus indicus,* and *strychnin.*

A broad distinction is to be drawn between the bitters first named and picric acid, cocculus indicus, and strychnin, since these are all of a highly poisonous nature.

Picric or *trinitrophenic acid*, formerly called *carbazotic acid*, or artificial *indigo bitter*, $C_6H_3(NO_2)_3O$, is obtained from a variety of substances, amongst others the following: carbolic acid or phenol, salicin, indigo, aloes, benzoin and other resins, and silk.

Picric acid crystallises in yellow, shining laminæ, composed of octahedrons, and sometimes in needles and granules. The crystals belong to the trimetric system.

It melts, when slowly heated, into a brownish-yellow oil, which becomes crystalline on cooling. It volatilises undecomposed at a low temperature, and at a higher temperature it boils, giving off a highly irritating vapour, which condenses into needles and scales.

When quickly heated it undergoes decomposition, accompanied by a violent explosion.

It possesses an intensely bitter and sour taste, and reddens litmus. In doses of from 1 to 10 grains many animals are killed, including rabbits and dogs, convulsions and delirium being produced. It is soluble in water in different proportions according to its temperature. One part of picric acid is dissolved in 86 parts of water at 15° C. and in 26 parts at 77° C., the solution being of a deep yellow colour, and concentrated it stains the skin. It is easily soluble in alcohol and ether, also in warm concentrated sulphuric acid, from which it is precipitated unchanged on the addition of water. Its power of imparting colour to water is really surprising. Water containing $\frac{1}{10000}$ part of picric acid is of a distinctly yellow colour, and if the quantity present be greatly below this, the colour may still be brought out by viewing the water in a stratum two or three inches in depth.

Cocculus indicus is the fruit of *Cocculus suberosus*, also named *Menispermum cocculus*. These seeds possess strongly narcotic and poisonous properties, due to the presence of an alkaloid called *picrotoxin*, $C_{12}H_{14}O_5$, which is present in it to the amount of 2 per cent.

This alkaloid is extracted by exhaustion with boiling alcohol. The alcohol is distilled off, the fatty matter is removed by boiling with a considerable quantity of water, and the aqueous extract mixed with a small quantity of neutral acetate of lead to remove colouring matter. The filtrate is freed from lead by means of sulphuretted hydrogen, evaporated, and the picrotoxin obtained by crystallisation.

From pure solutions it crystallises in stellate groups of needles, from coloured liquids in interlaced threads, which after a time change into more solid needles and even into laminæ.

It possesses an intensely bitter taste, and does not act on vegetable colours. It dissolves in 150 parts of cold and 25 parts of boiling water. It is very soluble in boiling alcohol and in ether.

Picrotoxin is highly poisonous, giving rise to giddiness, a species o intoxication, convulsions, and even death.

It reduces cupric oxide in the same manner as glucose, but it reducing power is less by about five times. It dissolves in strong sulphuric acid, forming a saffron-coloured solution, and with sulphuric acid and bicarbonate of potash the solution assumes a red-brown colour.

Strychnin is obtained from several species of plants of the genus *Strychnos*, especially *Strychnos nux vomica*; this genus also contains *S. St. Ignatii*, a plant yielding the beans of St. Ignatius, and *S. tieuté*, which furnishes the upas-tieuté, the Javan arrow poison.

Strychnin may be extracted from ground Ignatius beans or from nux vomica by exhaustion with alcohol. The alcohol is distilled off, the residue is dissolved in water, and a solution of basic acetate of lead is added. The strychnin remains in the solution, which is freed from the excess of lead by means of sulphuretted hydrogen and then boiled with magnesia. Thereby the strychnin is precipitated, and is then purified by repeated crystallisation from alcohol. 100 parts of nux vomica yield about 0·6 parts of strychnin.

Pure strychnin crystallises in white four-sided pyramids of the trimetric or rhombic system, which have the formula $C_{21}H_{22}N_2O_2$. It is soluble in 6,667 parts of cold and 2,500 parts of boiling water. It has an alkaline reaction, and since it resists putrefaction it may be extracted from bodies even after they have been buried for a long period; according to McAdam as long as three years.

Its solution is intensely bitter, and hence its reputed employment in the adulteration of bitter beer. It is extremely poisonous, one-eighth of a grain being sufficient to kill a large dog; and, since it is cumulative in its action, poisonous effects may be produced by the continued use of this alkaloid even in the minutest doses.

The following are the circumstances which induced the editor of the 'Lancet,' Mr. Wakley, to undertake, through the author, a very extended and rigorous enquiry into the subject of the alleged adulteration of beer with strychnin.

In the year 1850 a report came before the public in which it was asserted that the deadly poison strychnin is commonly employed by brewers in the manufacture of 'bitter beer' or 'pale ale.'

The following was the origin and foundation of this report:—

In the course of a lecture delivered at the Conservatoire des Arts et Métiers, M. Payen is asserted to have stated that strychnin was prepared in large quantities in Paris, and that the French authorities had ascertained that it was destined for England, it being employed in the manufacture of the celebrated bitter beer of that country.

This statement, after having appeared in some of the French papers, and amongst others in the 'Constitutionnel,' attracted the attention of some English journalists, who commented at some length upon it, incautiously treating the assertion as though its truth had been fully ascertained. At length the injurious statement made its way into the columns of the 'Times' newspaper, and thus became universally disseminated.

It was impossible for the brewers of bitter beer, the preparation of which is confined to a small number of persons, to pass by without notice so grave a charge, and one so immediately affecting their interests. Accordingly the two chief firms, those of Messrs. Allsopp & Sons and Messrs Bass & Co., lost no time in publicly denying, in the most unequivocal terms, that strychnin, or any other deleterious substance, was ever employed by them in the manufacture of their beer.

These celebrated brewers suggested that their bitter beer should be subjected to a searching chemical and microscopical examination, and expressed their willingness to place the enquiry in the hands of the Analytical Sanitary Commission. They offered to throw open their breweries, stores, &c., in the most complete and unreserved manner, and to afford every facility for the fullest investigation.

Feeling that the subject was one of great importance; that it involved the public health to a great degree, and also the pecuniary interests of a trade which, from its magnitude, had almost assumed a national character; that it also affected the judgment of the medical profession by whom the bitter beers had been so strongly recommended—Mr. Wakley ultimately agreed to undertake the enquiry upon the distinctly declared condition that the results of the investigation and analyses, whether favourable or unfavourable to the reputation and quality of the beer, should be unreservedly and faithfully communicated to the public.

In order to put the statement to the test, forty samples of bitter beer were subjected to analysis—twenty of the ale of *Messrs. Bass & Co.* and the like number of samples of the ale of *Messrs. Allsopp & Sons.*

They were all found to consist of the products of *malt* and *hops* and the constituents of *pure spring water*; no other ingredient of any kind being discovered, either organic or inorganic.

These samples were procured under circumstances which precluded the possibility of error, fallacy, or of preparation for the selection.

Under the above circumstances, and after the most scrutinising examination, microscopical, chemical, and physiological, we failed to detect the smallest atom of strychnin, or indeed of any other ingredients than the products of malt and hops and the constituents of pure spring water.

Unknown to, and wholly independent of ourselves, Messrs. Graham and Hofmann, at the request of Messrs. Allsopp & Sons, subjected several samples of their bitter beer to analysis. In their published report it is stated that they also failed to discover the slightest trace of strychnin.

It may be well to consider how far the statement made that strychnin is employed in the preparation of bitter beer is consistent with probability. In order to form an opinion on this point, it is necessary to obtain clear ideas of the quantity of this substance necessary to impart bitterness to a given bulk of fluid, to determine the chemical condition in which it exists in beer, and to ascertain the amount of strychnin which may be introduced into the system with safety to health and life. With respect to its bitterness, we find that one grain only of strychnin imparts a decided and persistent bitterness to at least 40,000 grains of water, or upwards of half a gallon; but the taste of the same quantity of strychnin is perceptible when diluted with 420,000 grains, or six gallons of water.

But it must be remembered that most beers contain free acetic acid in variable amount, and that, therefore, strychnin added to beer becomes converted into acetate of strychnia. Now this salt, although very bitter, is less so than strychnin itself; consequently, a larger amount of the combined alkaloid is necessary to impart the same degree of bitterness.

We have ascertained that no less than three grains of acetate of strychnia are needed to give a persistent and suitable bitterness to half a gallon of water; it is therefore evident that not less than one grain and a half of strychnin in combination with acetic acid would be required to impart such a degree of bitterness to the same quantity of beer as to render its use in the preparation of bitter beer a matter of any moment. Now a quantity of strychnin so considerable as this could not be taken in beer even without danger to life. Were the quantity present in beer much below this, its use would still be attended with the greatest danger, since this poison, like digitalis, colchicum, and certain other active vegetable products, is liable to be retained in the system, and to accumulate in it to such an extent as at length to give rise to the tetanic spasms and other consequences symptomatic of poisoning by strychnin.

From all these considerations, therefore, we conclude that the statement made concerning the use of strychnin in beer is scarcely consistent with probability.

Narcotics.—The hop is employed in the manufacture of beer, partly for its bitter, and partly on account of its narcotic, properties, and the same remark applies to *cocculus indicus*; but *tobacco* and *opium*, which have also been resorted to, are used mainly for their narcotic or soporific effects, which simulate somewhat those of the hop.

We believe that the employment of both tobacco and opium are so rare that it is scarcely necessary to enter into any long description of the composition and properties of the active principles contained in those substances. We shall, however, give the method for the detection in the one case of the nicotin and in the other of the morphin, which are their two most important and distinctive principles.

Carminatives.—The carminatives of the use of which there is evidence are *ginger*, *coriander*, *caraway seeds*, *cardamom seeds*, *grains of paradise* and *capsicum*, the whole of which will be found described in their appropriate places.

Mineral adulterants.—A great variety of mineral substances are employed in the adulteration of beer. Some of these are used to give the beer an appearance of strength and to make it froth, bead or 'head' well. The substances employed for this purpose are chiefly *sulphate of iron, alum,* and *salt*; others, as *chalk* and the *alkalies,* are used to correct undue acidity; and again others, as *sulphuric acid* and *cream of tartar* or bitartrate of potash, to give to the beer a tartness or hardness characteristic of age, and which is preferred by some beer drinkers.

It has already been stated that the law allows of the addition of a certain quantity of *salt,* which must not exceed 50 grains per gallon, including that contained in the water used in the brewing, and this addition it permits for no sufficient reason, lending its official sanction in this case, as in so many others, to the deterioration and adulteration of an important article of consumption.

It appears from our analyses that salt is almost constantly present in porter. This addition we know is made in the first instance by the brewers themselves; but there is also no doubt that a further quantity is frequently used by the publican to assist in bringing up the flavour of beer which has been reduced in strength by the addition of water. The quantity of salt contained in porter is often sufficiently large to communicate a perceptibly saline taste to the mouth. The salt is used by the brewers in the following manner:—It is first mixed up in a tub with flour, usually wheat flour, and the mixture is cast by handfuls over the surface of the wort in the cooling vat. It is said to assist in the preservation and fining of the wort, and it is alleged that these are the only purposes for which it is employed by the brewer.

The presence of *iron,* which is added chiefly to stout, causes it of course to be more strengthening and tonic, but iron is a tonic which does not suit all persons; and if it be desirable that we should take it at all, since it is a medicine, it should be administered in suitable cases only by the physician, and not indiscriminately by the brewer.

From different sources we obtain the following information in reference to the use of many of the substances above enumerated.

Mr. Phillips furnished the Committee on Adulteration of 1855 with the subjoined evidence in regard to the adulteration of beer:—

'It is chiefly *common salt* and *sulphate of iron* that are used for adulterating beer, and also *quassia.*'

Mr. Edwin Wickham's evidence was to this effect:—

'From my experience in brewing I believe that the great adulteration of beer takes place in the cellars of the publicans and not in the breweries, although I know it is done by some brewers.'

Mr. Scholefield. 'Do you believe that the adulteration of beer is a common thing?'—'Very common, so much so that the exception is not to adulterate; and I believe those exceptions are very few.'

Mr. Wickham gave the following as the receipt in frequent use amongst publicans for the adulteration of porter:—

'To one barrel of porter eight gallons of water, six pounds of sugar, one pound of gelatin (or patent size will do), a handful of common salt, extract of *gentian* or *quassia* to restore to it the original bitter flavour, *sulphate of ammonia* to bring it back to its colour, half an ounce of *sulphate of iron,* and if required to taste oldish, an ounce of *roche alum.*'

Again, Mr. Wickham affirmed—'I have known single instances of *tobacco* being used in beer.'

Mr. P. L. Simmonds, in evidence before the same Parliamentary Committee, stated that 'at least 250 tons of *cocculus indicus* are annually imported, chiefly, I suppose, for the use of brewers.'

He further stated that 'from 200 to 300 tons of the acrid seeds of *cardamom,* or *grains of paradise,* are also annually imported, and chiefly used to give an artificial strength to beer and spirits.' Also that 'cocculus indicus is commonly introduced into beer for the purpose of giving a false strength to it. In one case which came under my knowledge, the publican was found using it for the purpose of adulterating his beer to be sold the next day.'

Mr. Gay, in the evidence before quoted from more than once, gave the following information in regard to cocculus indicus:—

He stated 'I have ground many hundredweights of cocculus indicus.'

Mr. Moffatt. 'What is it used for?'—'I suspect to go into the poor man's drink.'

'For whom did you grind cocculus indicus?'—'For wholesale druggists.'

Mr. Rodgers alleged in his evidence that 'cocculus indicus can be obtained from the brewers' druggists under the name of *multum.*'

Mr. Simmonds also made this remark in his evidence—'In the suburbs of London I may mention that it is a common practice with the publicans to adulterate beer on Saturday nights much more than on other nights.'

He likewise deduced the inference that beer is extensively adulterated from the following statistical particulars:—

'There is one matter,' he observed, 'which occurs to me as being exceedingly singular, which is that the consumption of malt and hops continued stationary, though the consumption of beer, with the increasing population, must have increased very largely. In the last fifteen years there has been scarcely any variation in the amount of hops consumed, and some substances must therefore be used very extensively to make up the difference. The extent of land under cultivation for hops in the last three years has averaged 50,000 acres, being only 7,000 acres beyond the culture of thirty years ago. The home production in the last ten years has scarcely increased at all, and yet the shipments of beer and ale have more than trebled in value, and the home consumption must necessarily have increased also.'

Another fact, proving the extensive practice of adulteration in beer, was related by Mr. Wickham, in reply to the question by Mr. Swift:—

'Is it not customary for publicans to sell the beer at the price which they pay to the brewers, so that this adulteration forms their actual profit?'—'Yes, many publicans do so.'

Mr. Morris, who wrote a book some years since, entitled 'Brewing Malt Liquors' described and recommended a variety of articles to be employed in the brewing of beer and porter, as colouring, cocculus indicus, *sweet flag root,* quassia, coriander seeds, capsicum, caraway seeds, grains of paradise, ginger, *beans, oyster shells,* and alum. 'The colouring,' Mr. Morris remarked, 'gives a good face to the beer, and enables you to gratify the sight of your different customers.' And again, 'Beans tend to mellow malt liquor, and from their properties add much to its inebriating qualities; but they must not be used in too large a quantity. Oyster shells are very good to recover sour beer.

'Alum is generally put into the vat, as it gives the beer a smack of age.

'Cocculus indicus is used as a substitute for malt and hops, and is a great preservative of malt liquor. It prevents second fermentation in bottled beer, and consequently the bursting of the bottles in warm climates. Its effects are of an inebriating nature.'

Another writer, Mr. Child, also the author of a work on brewing porter, which went through eleven editions, gave the following receipt for making porter:—

1 quarter of malt.
8 lbs. of hops.
9 lbs. of treacle.
8 lbs. of liquorice root.
8 lbs. of essentia bina.
8 lbs. of colour.
Capsicum, half an ounce.
Spanish liquorice, two ounces.
Cocculus indicus, a quarter of an ounce.
Salt of tartar, two drachms.
Heading.
Ginger, three ounces.
Lime, four ounces.
Linseed, one ounce.
Cinnamon, two drachms.

The essentia bina, he states, 'is compounded of 8 lbs. of moist sugar, boiled in an iron vessel (for no copper one could withstand the heat sufficiently) till it comes to a thick, syrupy consistence, perfectly black and extremely bitter.'

Colour 'is composed of 8 lbs. of moist sugar, boiled until it obtains a middle state between bitter and sweet, and which gives to porter that mild, mellow colour usually so much admired.'

The heading 'is a mixture of half alum and half copperas, ground to a fine powder; and is so called from giving to porter the beautiful head of froth which constitutes one of its peculiar properties, and which landlords are so anxious to raise to gratify their customers.'

Other receipts by Mr. Morris are as follow:—

Malt, 25 *quarters.*

	cwt.	qrs.	lbs.
Hops	1	2	0
Cocculus indicus berry	0	0	6
Leghorn juice	0	0	30
Porter extract			

Malt, 20 *quarters*.

	cwt.	qrs.	lbs.
Hops	2	0	0
Cocculus indicus berry	0	0	4
Sugar	0	0	28
Fabia amara (nux vomica)	0	0	6

He also gave the following directions:—

To make up a Vat of 150 *Barrels.*

'Use half a barrel of colouring, a quarter of a hundredweight of cream of tartar, a quarter of a hundredweight of ground alum, one pound of salt of steel, and two barrels of strong finings. Mix these well together, and put them in a vat, rousing it thoroughly at the same time. Let the vat remain open three days, then close it and sand it over. In a fortnight it will be fit for use—your own good sense will inform you how to employ it to advantage.'

The extensive employment of various drugs for porter brewing led, many years since, to the establishment of a class of men termed 'brewers' druggists.' These persons issued regular price-currents, and they made it their business to send travellers all over the country with lists and samples exhibiting the price and quality of the articles manufactured by them.

Mr. Accum states that 'their trade spread far and wide, but it was amongst the country brewers chiefly that they found the most customers, and it is amongst them, up to the present day, as I am assured by some of these operators, on whose veracity I can rely, that the greatest quantities of unlawful ingredients are sold.'

'It was at the same time, also,' writes Accum, 'that a Mr. Jackson, of notorious memory, fell upon the idea of brewing beer from various drugs without any malt and hops. This chemist did not turn brewer himself, but he struck out the more profitable trade of teaching his mystery to the brewers for a handsome fee. From that time forwards, written directions and receipt-books for using the chemical preparations to be substituted for malt and hops were respectively sold; and many adepts soon afterwards appeared everywhere to instruct brewers in the nefarious practice first pointed out by Mr. Jackson.'

The following remark, contained in Dr. Normandy's work, entitled 'Commercial Handbook of Chemical Analysis,' would lead us to infer that the fraternity of brewers' druggists is not even yet extinct:—

'It is a publicly known fact that carts may be seen bearing the inscription, in staring paint, of "C——; brewers' druggists." Such a cart I have myself seen a few days ago standing, in the broad light of midday, before a publican's shop or gin palace.'

Some idea of the extent to which porter is adulterated may also be formed from the two following circumstances:—

It has been shown before the Parliamentary Committee on Public-Houses, on the clearest evidence, that it is quite impossible for a publican to realise any profit by the sale of beer without having recourse to adulteration.

Again, Mr. M Culloch, a witness before the same Committee, not only deposed to the fact of the extensive adulteration of beer by publicans, but he also estimated the loss to the State arising out of that adulteration at 100,000*l.*, in consequence of the diminished consumption of malt.

Not only is beer itself adulterated, but frequently the very materials out of which it is made are also adulterated, as the hops and malt.

The Adulteration of Malt.

Barley is sometimes substituted for malt, to the great loss of the revenue.

The Adulteration of Hops.

In regard to the adulteration of hops, Mr. Phillips gave the following information before the Committee on Adulteration in 1855:—'Most of the 40 samples of hops I have spoken of contained *grains of paradise*; in one instance we had *cocculus indicus*, but only in one instance.'

These 40 samples of hops were examined by the Excise in twelve years, and out of them 35 were found to be adulterated, the substances met with being *grains of paradise*, *quassia*, *chiretta*, *gentian*, *camomile flowers*, *coriander seeds*, and in one instance *cocculus indicus*, and in another, exhausted *tobacco*.

Results of the Examination of Samples of Porter and Stout.

The results of the chemical examination of *fifty-two* samples of *stout* and *porter*, there being thirty-two of the former and twenty of the latter, procured both from brewers and publicans, were:—

The samples of STOUT either obtained from agents, or purchased at the taps of several of the principal London porter brewers, were considerably stronger than those procured from publicans; the alcohol, of specific gravity ·796, temperature 15·5° C., contained in the former samples ranged from 7·15 per cent. by volume the highest, to 4·53 the lowest; whereas that of the stouts procured from publicans varied, with one exception, from 4·87 per cent. to 3·25 per cent.

The same difference of strength also characterised the various samples of PORTER procured from the two different sources; the amount of alcohol in the porters obtained from the taps varying from 4·51 per cent. to 2·42 per cent.; whereas those purchased of publicans ranged from 3·97 per cent. to 1·81 per cent.

In nearly all the stouts and porters *salt* was present, often in considerable amount.

In some of the samples *cane sugar* and *treacle* were likewise present.

Great as was the variation in the strength of the different samples, arising mainly from dilution with *water*, there is no doubt but that if the porter and stout had been procured direct from the brewers, in place of from the public-houses known as brewers' taps, the difference would have been found to be still greater.

Such is the simplest form which the adulteration of these beverages assumes; not unfrequently it takes a more complicated and serious form.

The receipt or formula according to which the majority of articles of consumption are adulterated, is an exceedingly simple one.

First there is something added to augment the weight and bulk of the article; then something to restore the lost colour; and lastly, something to give to the adulterated and weakened compound, as far as possible, the taste and qualities possessed by the genuine commodity.

It is according to this formula that porter and stout are adulterated; first *water* is added to increase the bulk, and then *treacle*, *sugar*, and *salt*, to restore the colour and flavour.

The dilution of the beer makes it less intoxicating, and hence the occasional use of a variety of the other articles intended to impart to it the semblance of strength.

Mr. Phillips found that *grains of paradise* had been added in 14 out of 20 samples subjected to analysis.

Out of 20 samples of adulterated beer, examined in 1863, Mr. Phillips found *cocculus indicus* in large quantities in two instances, and in one *tobacco*.

The remedy by which the adulteration of malt liquors may be met appears to us to be clear and simple, and it is one to which we some years since had the opportunity of directing the attention of the Committee of the House of Commons on Public-Houses; it is, *that no malt liquors should be permitted to be sold by any publican under certain fixed or standard strengths*, the tests of strength being not the specific gravity of the beers, but principally the amount or percentage of alcohol contained in them.

Such a regulation, properly enforced, would effectually put a stop to the adulteration of malt liquors by the addition of water, sugar, salt, and most of the other substances mentioned in this report; and it need not in any way interfere with the different recognised strengths and qualities of malt liquors now in use, as single and double stouts, ales, and porters.

It having been proved that beer is very extensively adulterated, let us now enquire how far the Excise at the time when the above analyses were made protected the revenue in the case of this article.

As has been shown, *malt* and *hops*, the ingredients used in brewing beer, are both adulterated, as is also the *beer* itself.

It appears from the evidence of Mr. Phillips, already quoted, that the Excise, with its 70 chemists and 4,000 inspectors, in the course of twelve years, examined only 40 samples of *hops*, of which 35 were adulterated.

With regard to *malt*, the Excise was then in a state of happy ignorance, as appears from the following remarks of Mr. Phillips:—

Mr. Villiers. 'What information can you give us respecting malt?' —'The fact is, we have been in some difficulty about that, and I believe we have arrived at a means by which we can detect any mixture. It is possible we may have been defrauded of malt duty by the mixture of grain; some traders assert we have largely, but I cannot say of my own knowledge.'

'What would be the nature of the mixture?'—'Chiefly barley, I suppose.'

The Excise was but little better informed respecting *beer*. Of 1,139 samples examined by the Excise in twelve years, taken, when about to be exported, from vessels for the purpose of ascertaining their gravity so that the drawback might be allowed, that scientific body succeeded in discovering adulteration in only twelve samples.

Such is a summary of all that the scientific department of the Excise at the time referred to had been able to effect in discovering adulterations in hops, malt, and beer.

THE DETECTION OF THE ADULTERATIONS OF MALT BEVERAGES.

Detection of water.—The presence of added water can only be inferred when the specific gravity, total solids, including mineral matter, and alcohol, are all below those characteristic of beer of good quality. Hence it is necessary that the analyst should be furnished with certain authoritative standards to guide him. What these standards should be we have already endeavoured to indicate in the definition given at the head of this article. It may seem somewhat arbitrary to prohibit a brewer from making malt beverages of any strength he thinks fit; but, inasmuch as he sells these beverages under certain distinct names, as beer, ale, porter, and stout, it is only just that the public should have the means of knowing what those names really signify, and this knowledge must be based upon the actual composition of these beverages.

It is not insisted that they should always be of one invariable strength and composition, but only that they should never be permitted to fall below a certain very moderate standard. In no other way than this is it possible to prevent the adulteration of malt beverages with water.

Standards of comparison are equally required, as we have already seen, in the case of milk and spirits.

Detection of cane sugar.—Under this head we include molasses and treacle, since these contain a considerable portion of cane sugar. Of course if cane sugar be added to the wort, it will no longer exist as such in the fermented beverage; it will all have been transformed into glucose and alcohol, and hence its discovery would be possible only by indirect methods, that is to say by detecting in the sediment of the beer either the sugar acarus or the dotted and characteristic particles of the sugar-cane.

When, however, the cane sugar has been added, as it frequently is after the fermentation of the beer, as when two barrels of beer are made by the publicans into three barrels—a common practice, as has already been explained—then its discovery is more practicable. Not unfrequently crystals of cane sugar may be obtained by the careful evaporation of the extract of the beer, especially if the sugar has been added in the raw state, and not as treacle. Or the cane sugar may be estimated after its conversion into glucose by boiling in the usual manner with dilute sulphuric acid. Of course the dextrin proper to the beer is converted at the same time, but there should be a certain relation, more or less definite, between the amounts of starch sugar and dextrin in genuine beer, a relation which would be entirely destroyed if cane sugar had been added.

Again, in this case there is an increased chance of detecting by the microscope in the residue of the beer the sugar acarus and the fragments of the sugar-cane.

Detection of liquorice.—This substance is usually added to the porter or stout in the same manner as the cane sugar after fermentation. If liquorice has been employed in the adulteration of any beer, we believe that its presence would be sufficiently indicated by the taste of the carefully evaporated extract, and again, since stick liquorice is almost always adulterated, very frequently with different kinds of flour or starch, and since also it is usually much contaminated with copper, we are furnished in these particulars with methods whereby in some cases it would be possible to detect the presence of liquorice in beer.

For the flour or starch search should be made in the deposit in the cask, which may be readily obtained by means of a long glass tube, while for the detection of the copper a considerable amount of the beer, including some of the residue at the bottom of the cask, should be evaporated, the residue incinerated and the ash tested for copper in the usual manner.

Furthermore liquorice contains a peculiar form of sugar, named *glycyrrhizin*. This is distinguished from other sugars by being unfermentable and by its solubility in ether, whereby it may be extracted from the residue of the beer obtained by evaporation.

Detection of burnt sugar.—Since black or patent malt contains a large amount of burnt sugar, it is of course not possible to state in any case whether that substance has been directly added to the beer, or whether it has been introduced through the malt employed.

According to R. Schuster ('Dingler's Polyt. Journ.') genuine beer, when shaken with a solution of tannin, becomes decolorised, while that coloured with burnt sugar still retains the greater part of its colour.

Detection of vegetable bitters.—Several of the bitter substances referred to under the head of the adulteration of beer contain active crystallisable substances, which in some cases will serve for the identification of the bitter. This is notably the case with gentian, quassia, and wormwood. *Gentian* contains a crystallisable acid, called *gentianic acid*, having the formula $C_{14}H_{10}O_5$; this is not, however, the bitter principle of the root.

Quassia also contains a crystallisable substance, to which the bitterness of the root is due, and which is termed *quassin*. It is obtained from the root by extraction with alcohol, the crystals being small white opaque prisms, permanent in the air, inodorous, and possessing a very bitter principle.

The active principle of *wormwood* is *absynthin*, $C_{16}H_{22}O_5$.

For further details respecting these substances see 'Watts's Dictionary.'

Mr. Sorby states that he can detect, by means of the spectroscope, *calumba root* when present in the proportion of not less than 2 ounces in the gallon. He evaporates a portion of the suspected beer, exhausts the syrup with alcohol, and evaporates this solution to dryness. A solution of hypochloride of soda is then added, and the spectrum observed. Genuine beer will give a spectrum 7 . . 8 – – 9—of Sorby's scale, while calumba root furnishes one at 3½ . . 4½ – – 5.—Sorby, 'Quarterly Journal Microscopical Science,' vol. xxxvi.

The other substances named are *chiretta*, *bitter orange peel*, and *camomile*, but little is as yet known of the chemistry of these substances, and it is uncertain whether they contain any active principles or not which would allow of their identification.

Hence in the present state of science it may be inferred that it would be impossible to identify in all cases the bitter substances employed in the adulteration of beer, and as a substitute for hops. Still, in many instances it would be practicable to establish the fact that some bitter substance has been added to beer other than the lupulin of the hop.

Detection of picric acid.—M. Lassaigne finds that this substance is not precipitated by subacetate of lead, which throws down most of the other colouring matters of beer, as well as the bitter principle of hops, and also that it is not absorbed by common bone charcoal thoroughly purified by acids. By means of one or other of these substances, he succeeds in obtaining a tolerably pure solution of picric acid. M. Lassaigne states that while pure beer is almost entirely decolorised by either subacetate of lead or purified bone charcoal, beer adulterated with the one twelve-thousandth, or even the one eighteen-thousandth part of picric acid, remains of a yellow citron colour. Supposing the beer to contain a still more minute quantity of picric acid, it must, subsequent to the use of one or other of the above substances, be evaporated until the yellow citron colour is produced. It is possible that by the above method picric acid might be detected in poor and pale beers, but we very much doubt whether it would be successful in the case of London stout and porter, which are not entirely decolorised by either subacetate of lead or purified charcoal.

Should picric acid be present, the beer will retain its bitterness after the precipitation of the bitter principle of the hop by means of subacetate of lead.

But a still more delicate test is the property which picric acid possesses of imparting a yellow colour to wool, first employed for its detection by Pohl. In fact, if the wool be retained in the beer for a sufficient length of time, the whole of the picric acid will be precipitated upon it.

The beer is boiled with some unbleached wool for about ten minutes. The wool is then removed and washed. When the beer is pure the wool will remain white, but if it contain even one part of picric acid in 125,000 parts of beer, the wool will be dyed of a yellow colour.

But since other colouring matters of the beer are also precipitated upon the wool, it has occurred to H. Brunner to separate the picric acid from the wool by extracting it with hot aqueous ammonia. The solution is concentrated on the water-bath to a very small bulk, and a few drops of a solution of cyanide of potassium are added. If the minutest trace of picric acid be present, a red coloration of isopurpurate of potassium will be produced. By this method one part of picric acid in 500,000 parts of water may be detected.

Detection of picrotoxin.—The active principle of cocculus indicus is picrotoxin, the presence of which in beer may fortunately be discovered by the method about to be described, devised by the late Dr. Herapath.

Dr. Herapath has directed that the beer or porter should be first treated with excess of acetate of lead, so as to throw down all gum and colouring matter. The clear liquor is then to be separated by filtration, and the excess of lead precipitated by sulphuretted hydrogen. After standing for some time, or boiling so as to get rid of uncombined sulphuretted hydrogen, it is to be filtered again. The liquor thus obtained is to be evaporated at a moderate temperature until it becomes rather thick, and then treated with a little pure animal charcoal. After agitation and the lapse of a few hours, the charcoal is collected on a filter, washed with very little water, and dried on the water-bath. The charcoal contains the picrotoxin, which may be separated by boiling with a little pure alcohol, filtering, and evaporating to dryness on slips of glass. It is recognised by its forming plumose tufts of acicular crystals, or else oat-shaped forms. If greater time be allowed in the evaporation the picrotoxin crystallises in quadrilateral prisms.

Dr. Langley, of Michigan, recommends the acidulation of the beer with hydrochloric acid and agitation with ether, which dissolves out the picrotoxin—the hydrochlorides of the other alkaloids being insoluble in that menstruum. The ethereal solution is then evaporated, when the crystals of picrotoxin may be further tested 'by rubbing with nitrate of potash, adding a drop of sulphuric acid, and then a strong solution of potash or soda. A bright reddish-yellow colour is given if picrotoxin be present.'—*Parkes.*

Detection of nux vomica and strychnin, opium and morphin, and tobacco and nicotin.—At least one gallon of the beer is evaporated on the water-bath at a temperature, which should never rise above 80° C. The syrupy residue is extracted with repeated quantities of cold absolute alcohol, and the alcoholic solution evaporated on the water-bath at a temperature not exceeding that above mentioned. The liquid, which is strongly acid, is to be very nearly, but not quite, neutralised by means of soda solution, and it is then well shaken with pure ether. The ether takes up the picrotoxin, if present, and the ethereal solution is to be evaporated and tested for the alkaloid.

The liquid, after the removal of the ether by heating it, is now to be rendered distinctly alkaline by means of soda, whereby the alkaloids are liberated; it is again well and repeatedly shaken with pure ether, and after an hour or two the ether is separated and evaporated at a very low temperature in a glass basin or large watch-glass. The ether will dissolve the strychnin and nicotin but not the morphin, which remains in the alkaline liquid. If on the evaporation of the ether no residue remains, no alkaloid can be present, but if an oily and strongly smelling liquid is obtained, the presence of tobacco in the beer may be suspected. If a crystalline deposit is formed, strychnin would probably have been used.

The residue, if any, whether oily or crystalline, is tested as follows:—A portion is slightly heated. A smell of tobacco would reveal the presence of nicotin beyond all doubt.

To another part of the residue a small fragment of chromate of potash and a drop of sulphuric acid are added. The slightest trace of strychnin will be detected by the liquid assuming a deep and beautiful violet-blue coloration.

For the detection of morphin, the solution is acidulated with hydrochloric acid, next rendered slightly alkaline by means of ammonia, and then well shaken with pure fusel oil, in which, especially when slightly warmed, the morphin is easily soluble. The fusel oil is to be separated from the watery solution, and it is then to be evaporated on the water-bath. If morphin be present it will remain in the form of microscopic needles. This residue may be further tested, and the presence of morphin will be proved, if its concentrated solution separates iodine from a solution of iodic acid, and if it, when heated in the water-bath for a quarter of an hour with a few drops of concentrated sulphuric acid containing a little nitric acid, produces a violet coloration. This latter reaction is very distinctive of morphin.

The following process for the detection of strychnin has been published by Mr. Rodgers:—'The evaporated extract of the beer is digested, after the addition of a little hydrochloric acid, in an evaporating basin, then strained and evaporated to dryness over a water-bath; digest the residue in spirit, filter, and again evaporate to dryness; treat with distilled water acidulated with a few drops of hydrochloric acid, and filter; add excess of ammonia, and agitate in a tube with chloroform. The strychnin in an impure condition is entirely separated with the chloroform. This chloroform solution is to be carefully separated by a pipette and poured into a small dish, wiped to dryness; the residue evaporated, moistened with concentrated sulphuric acid, and heated over a water-bath for half an hour; water is then added and excess of ammonia, the mixture being agitated once more with chloroform, when the strychnin will be again separated, now in a state of sufficient purity for testing, which can be done after evaporating a few drops on a piece of white porcelain.'

Detection of carminatives.—The carminatives employed in the adulteration of beer may be divided for the most part into two classes. In the one the active principles are not dissipated by the temperature of boiling water, and hence they will be found in the extract of the beer, evaporated on the water-bath. To this division belong ginger, capsicum, and grains of paradise. The active principles of these may be separated from the extract of beer by treating it with alcohol, evaporating the alcoholic solution nearly to dryness, and exhausting the residue with ether, in which the lupulin is insoluble. The ethereal solution may now be evaporated and tested. The taste will afford a sufficient distinction between the named substances, but if any doubt be entertained as to the presence of capsicin this will be dissipated by burning the extract, fumes of an intensely acrid character being evolved.

In the other division the active principles consist of volatile oils, as in caraway and coriander. In this case the only chance of discovery is by the distillation of a given quantity of the beer, say 500 cc. Any volatile oil present will be found in the distillate, and its presence would be revealed by its odour and taste.

Detection and estimation of sulphate of iron.—Take half a litre of the beer, evaporate, and incinerate the residue. If iron be present in as small a quantity as one part of the sulphate to 315,000 parts of beer, equal to 2 grains in 9 gallons, the ash will be of a reddish colour, whereas in genuine beer it is always white or greyish white. The ash is boiled with strong hydrochloride acid, and the liquid tested with a solution containing both ferrocyanide and ferricyanide of potassium, which will give a blue precipitate of Prussian blue if iron be present.

For the quantitative estimation of the iron proceed as directed under 'Tea.'

Detection and estimation of alum.—Incinerate the residue of from one to two litres of beer, and proceed as described under 'Bread.'

Estimation of salt.—Evaporate 250 cc. of the beer to dryness, incinerate and dissolve the ash in pure nitric acid ; filter and precipitate in the filtrate the chlorine by means of a solution of nitrate of silver. The chloride of silver obtained is collected, washed, dried and weighed.

It is usually recommended to estimate the chlorine volumetrically from the neutral solution of the ash, but this method of proceeding gives very erroneous results, inasmuch as the phosphates contained in the beer are likewise precipitated by the standard silver solution.

Estimation of lime, soda, potash, and sulphuric acid.—In making an analysis of beer with a view to determine whether it contains any excess of the above substances, it is necessary to refer to the analyses given below of the ash of genuine beer, and to deduct from the quantities found the normal amounts present in the ash.

Again, the alkalinity of the ash must be estimated. If this be considerable it will show that some alkaline earth or alkali has been added, the exact nature of which will be revealed on further analysis.

The methods for the estimation of the whole of the above-named substances will be found fully described in the article on 'Tea.'

So far we have said nothing about the estimation of sulphuric acid in beer. This may exist in two states, either combined or free. If in the former condition, it is no doubt derived from the water used in brewing, or from the sulphate of iron or alum employed in the adulteration of beer. The water used by the Burton brewers contains, as has already been noticed, large quantities of sulphate of lime.

For the estimation of the free sulphuric acid, see 'Vinegar.'

Detection of cream of tartar.—To a portion of beer alcohol is added until the precipitate formed begins to be permanent—that is to say, is not entirely dissolved on agitating the mixture. The beer is allowed to stand for twenty-four hours, when, if cream of tartar be present, this will have separated in a crystalline state. It may be collected, incinerated, and from the alkalinity of the ash the amount of bitartrate of potash may be calculated.

Analyses of the Ash of Beer.

	London Beer.	Munich Beer.	Speyer Beer.	Scotch Ale (14 samples).	Scotch Porter (2 samples).	Dublin Porter (2 samples).	London Porter (5 samples).
Potash	38·35	36·58	37·68	3·2–29·8	18·9–20·9	21·4–32·0	4·9–31·1
Soda	7·68	9·03	6·59	20·9–38·5	33·8–38·8	24·0–42·7	21·8–50·8
Lime	2·45	1·48	2·98	0·2– 2·0	1·3– 1·6	0 8– 1·5	0·8– 6·9
Magnesia	3·78	5·64	4·66	0·1– 5·6	0·2– 1·4	0·2– 1·2	0·1– 1·2
Sulphuric acid	1·36	1·68	2·56	1·6–19·2	2·2– 6·4	2·8–10·1	1·6–12·2
Chlorine	2·75	3·14	2·14	4·3–18·25	7·4–11·4	6·9–10·1	6·5–14·5
Silica	9·87	9·96	10·29	4·6–19·1	13·3–18·6	6·9–19·7	8·2–19·7
Phosphoric acid	33·76	31·69	33·10	6·0–25·7	12·5–18·8	7·9–20·0	9·3–20·6

The above table is taken from 'Watts's Dictionary.' The first three analyses are by Walz, the rest by Dickson.

The Detection of the Adulterations of Hops.

The several substances elsewhere enumerated as having been discovered in hops may all be readily discerned, frequently by the eye alone, and invariably by the microscope. The structure of cardamom seeds, or grains of paradise, the article most frequently employed, will be found described and figured under the head of 'Curry Powder.'

CHAPTER XLIV.

CIDER AND PERRY AND THEIR ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any other added constituents than those derived from the juice of the apple or pear ; any added water, sugar, or spirit.

CIDER, as all the world knows, is the fermented juice of the apple.

The varieties of apple are exceedingly numerous. They have been ranged in three classes—the sweet, the bitter, and sour kinds. The best of these is the bitter ; these yield a juice richer in sugar, the cider made from it being brighter and keeping longer. As a rule, it may be said that those apples make the best cider which furnish a juice of the highest density.

Berard has given the following percentage composition of the *apple* :—

Water	86·28
Sugar	6·45
Ligneous matter	3·80
Gum	3·17
Malic acid	0·11
Albumen	0·08
Chlorophyl	0·08
Lime	0·03
	100·00

The exact composition of the juice of the apple varies, of course, according to the degree of ripeness, the kind of apple, season, climate, and soil.

According to Schulze, the specific gravity of apples and pears ranges between 0·72 and 0·91, and they contain from 13 to 21 per cent. of solids, of a specific gravity of 1·4. The specific gravity of the fruit would indicate that it contains a considerable quantity of some gas, most probably carbonic acid gas.

The quantity of sugar contained in apples varies especially with the degree of ripeness of the fruit. The sugar is stated in 'Watts' to amount, on the average, in the unripe fruit, to 4·9, in the ripe to 11·0, and in the over-ripe to 7·95 per cent., the higher amount being equal to 5·1 per cent. by weight of alcohol.

To make good cider it is necessary that the apples should be ripe, but not over-ripe; and in order to ensure their ripeness, they are kept for a month or so after being gathered. In Devonshire and some other places the apples are collected in heaps under the trees, where they are allowed to remain until they become sufficiently ripe. Ure states, however, that too much care cannot be taken to separate the sound from the spoiled or decayed apples, for the latter furnish an acid leaven, impart a disagreeable taste to the juice, and prevent the cider from fining properly. The unripe apples should also be separated, since they contain too small an amount of saccharine matter.

During the process of the ripening of the apple, the mucilage is diminished; and a volatile oil of a yellowish colour, and of a sharp and harsh taste, are formed; this oil boils at 190° C., dissolves sparingly in water, but readily in alcohol and ether: it forms a crystalline compound with hydrochloric acid, and is decomposed by chlorine.

An artificial apple oil is made by dissolving valeriate of amyl in 6 or 7 parts of alcohol.

In its unfermented state the *juice* consists mainly of *mucilage, glucose, nitrogenous matter, malic acid,* together with a small quantity of *acetic acid,* these several constituents being held dissolved in a large quantity of water.

The specific gravity of the juice of 20 different sorts of apple, according to Schulze, ranged between 1020 and 1027; and in two instances it reached the gravities of 1033 and 1037.

The acid in the juice, according to the same authority, ranged between 0·48 and 1·13 per cent.

It is stated in 'Watts's Dictionary' that in Würtemberg the specific gravity of the juice in warm seasons reaches 1080, and even approaches 1090. The free acid, estimated as tartaric acid, amounts to from 0·4 to 1·2 per cent. and the sugar from 4 to 10 per cent.

It would appear that the gravities of 1020 to 1027, mentioned above, are much too low. Couverchel has given the following table of the specific gravities of the juice of different kinds of apple. The gravities range from 1060 to 1094, the average being 1072:—

Green reinette	1094
English reinette	1080
Red reinette	1072
Musk reinette	1069
Touillet rayé	1064
Orange apple	1063
Reinette of Caux	1060

According to Dr. Richardson, the *ash* has the following percentage composition:—

Potash	35·68
Soda	26·09
Lime	4·08
Magnesia	8·75
Sulphuric acid	6·09
Silicic acid	4·32
Phosphoric acid	12·34
Phosphate of iron	2·65
	100·00

MANUFACTURE OF CIDER.

The apples are reduced to a state of pulp, either by means of stones or by revolving cylinders and knives, as is done in the case of the sugar-beet.

According to Ure, when the fruit is half mashed, about one-fifth of its weight of river-water is added. We should have considered that this addition of water would prove exceedingly detrimental to the quality of the cider, and we can scarcely think that the practice is one generally adopted.

Ure also states that, after the apples are crushed, they are put into a large tub or tun for 12 or 24 hours. 'This steeping aids the separation of the juice, because the fermentative motion which takes place in the mass breaks down the cellular membranes, but there is always a loss of alcohol carried off by the carbonic acid disengaged, while the skins and seeds develop a disagreeable taste in the liquid. The vatting might be suppressed if the apples were so comminuted as to give out their juice more readily.'

Muspratt has thus expressed himself in regard to the vatting of the fruit after it has been crushed :—'There can be no doubt that this procedure is attended with good results, and it is probable that sufficient importance is not attached to it, since many ciderists carry the pulp at once from the mill to the press. Even during the short process of grinding, the air changes the colour of the mass to a deep red, though whether this is produced by the absorption of oxygen or from the action of the constituents of the fruit upon each other has never been accurately ascertained. It is most probable, however, that each cause has an influence depending on the other. Certain it is, that when the juice is at once expressed from the apples it is a meagre thin liquid, while that of the poorest fruit, when exposed for some hours to the air, becomes quite red and runs sweet and luscious, when, after being well ground, the pulp is submitted to the press.'

The pulp is now put into hair cloths, from 3½ to 4½ feet square, and when the sides are folded over the contents the layer of pulp is about 6 inches in thickness. Formerly mats made of reeds or straw were employed, but their use has been long discontinued.

The mashed fruit is subjected 'stratum super stratum' to strong pressure, till what is called a cheese or cake is formed. The mass is to be allowed to drain for some time before applying pressure, which ought to be very gradually increased. The juice which exudes with the least pressure affords the best cider. That which flows towards the end acquires a disagreeable taste from the seeds and skins. The must is put into casks with large bung-holes, where it soon exhibits a tumultuous fermentation. The cask must be completely filled in order that all the light bodies suspended in the liquid when floated to the top by the carbonic acid may flow over with the froth. Flat tubs are placed under the casks to catch the overflowings.

The cake left after the expression of the juice is taken out of the press, divided into small pieces, and mashed anew, about half its weight of water being added. The mass is again subjected to pressure. A much poorer cider is thus obtained, which, as it will not keep, requires to be drunk soon after being made. The cake is again mashed up with water and squeezed, when a liquor is obtained which may be used for moistening fresh-ground apples.

Some three or four days usually elapse after the introduction of the must into the casks before fermentation sets in, but the exact time varies according to temperature and other circumstances. After the completion of the fermentation the liquid becomes clear and bright and exhibits its characteristic vinous colour.

It is now racked off into other casks, the sediment being put into linen bags; a further quantity is thus filtered off and added to that first obtained.

Sometimes it is necessary to make use of finings, as isinglass, albumen, or blood, as in the case of beer and wine.

The changes which the juice undergoes during the vinification are precisely analogous to those which wort and must undergo under similar circumstances. Alcohol and carbonic acid are formed at the expense of the sugar, while the malic acid imparts piquancy to the beverage, part of the aroma and flavour being due to the volatile apple oil, which is held in solution by the spirit.

A considerable period must elapse, however, before the cider really becomes ripe and fit for sale. Usually the casks are moved into cellars in January, and in March they are bunged down, when it has become fit for sale; but it will be gradually improved by further keeping. Sometimes the cider is stored in vats holding as much as 2,000 gallons each. The cider for bottling and effervescing cider should be bottled in September or October of the following year; some persons, however, bottle it in April or May.

According to Brande, the strongest cider made contains 9·08 per cent. by volume of alcohol, and the weakest 4·79 per cent., but it is stated in 'Watts's Dictionary' that the largest amount of sugar contained in the apple is 11·0 per cent., a quantity which is incapable of yielding the high percentage of alcohol above mentioned.

Muspratt says it is common to mix with the new cider about to be bottled a portion of old and sound liquor of the previous year's manufacture, with a view to check the progress of the fermentation and the consequent bursting of the bottles.

Acetic acid is very quickly developed in cider, rendering it sour and hard.

It is said that cider or perry will not keep if it be removed in cask after it has been prepared; and, according to Dr. E. Smith, in order to fortify it to bear a journey in cask it is common to add sugar. 'This so far injures it that it may renew the acetous fermentation, but it temporarily masks the acid flavour and makes the fluid more agreeable to the palate of those not accustomed to its use.'

Spirit puncheons preserve cider better than any other casks. Sometimes sulphur is burnt in the casks before the introduction of the cider.

PERRY.

The remarks hitherto made in reference to the composition of the apple and the manufacture of cider, apply for the most part also to the pear and the preparation of perry.

The composition of the pear resembles very closely that of the apple, but it usually contains a larger proportion of sugar. It likewise contains traces of pectic and gallic acids and an essential oil. In consequence of the larger amount of sugar, perry is usually richer in alcohol than cider. It is said to contain, on an average, 10 per cent. alcohol by volume.

ADULTERATION OF CIDER.

Perry and cider appear to be but little liable to adulteration. Like the other alcoholic beverages they are prone to have their strength reduced by the addition of *water*. In fact, this addition, as we have already seen, is sometimes made to the apple-juice itself. But in whatever stage the water be added, it must be regarded, we consider, in the light of an adulteration.

Another practice is to colour cider with *burnt sugar*. This proceeding, as we have more than once insisted, is objectionable, because in some cases it impairs the delicate flavour of the article to which the bitter burnt sugar is added; and since the colour thus produced is often unnaturally deep, and therefore offensive to the eye of a real connoisseur.

Cider, as already pointed out, is exceedingly apt to pass into the acetous fermentation. The excess of acid is very frequently removed by the use of an alkali, as *soda, chalk,* and formerly even of *litharge,* which is *oxide of lead.*

The use of such a substance as oxide of lead for the correction of the acidity has often given rise to injurious and in some instances to fatal results, colic and even paralysis frequently ensuing.

Dr. Muspratt, in his 'Dictionary,' has thus expressed himself in reference to the addition of lead to cider in order to correct any undue acidity:—'This practice cannot be too strongly condemned. It is only very lately that the editor had to examine a beverage, which had caused most serious inconvenience to a whole family, including colics, bilious obstructions, and other dangerous complaints. It was found to be contaminated with a very notable quantity of lead. Upwards of two thousand years ago it was known that lead had a most injurious effect on the animal economy. The ancients were very scrupulous as to the use of anything containing that metal; its presence in articles of daily consumption is to be dreaded. For many, by misplaced confidence, have arrived at an untimely end, or at least have been affected with that disease termed the Devonshire or painters' colic, and, in numerous instances, paralysis has been the final result.'

'The leaden beds of presses for squeezing the fruit in cider countries,' Accum writes, 'have produced incalculable mischief. These consequences never follow when the lead is combined with tin, because this metal, being more eager for oxidation, prevents the solution of the lead.'

Sometimes the excess of acidity is masked, but of course not removed by the addition of *sugar*. We have not met with any statement respecting the fortification of cider and perry by the addition of *spirit*, but such a proceeding would appear to be one very likely to be adopted in some cases.

Results of the Analysis of Samples.

	Specific Gravity.	Alcohol by weight.	Malic Acid.	Acetic Acid.	Sugar.	Total Solids.	Mineral matter.
1	1012·92	4·70	0·364	0·086	3·63	5·76	0·27
2	1013·08	4·88	0·328	0·111	3·96	6·14	0·53
3	1012·84	4·76	0·329	0·118	3·75	5·38	0·22
4	1001·92	5·01	0·368	0·119	1·72	2·67	0·29
5	1011·64	4·88	0·310	0·133	3·83	5·18	0·24
6	1012·40	4·88	0·343	0·111	3·91	5·33	0·22
7	1027·68	2·08	0·367	0·177	5·82	7·63	0·37
8	1028·96	2·32	0·533	0·053	6·30	8·94	0·27
9	1007·48	4·39	0·224	0·088	2·83	3·64	0·23
10	1015·64	3·67	0·332	0·040	4·38	5·65	0·23
11	999·20	5·07	0·302	0·151	1·09	1·80	0·18
12	998·36	4·76	0·310	0·146	1·04	1·66	0·16

Samples 1 to 6, inclusive, consisted of draught or still cider manufactured by different makers, and were obtained from different public and eating houses in London; samples 7, 8, 9 and 10 were effervescing or champagne ciders prepared by four different manufacturers; while, lastly, samples 11 and 12 consisted of Herefordshire cider, obtained from a gentleman who bottled it himself for his own use. For the whole of these samples we are indebted to Messrs. Welch & Mac Gill, wine merchants, 134 Fenchurch Street, E.C.

ANALYSIS OF CIDER.

The analysis of cider and perry is almost identical with that required in the case of malt liquors; it has already been described at length in the article on those beverages.

The specific gravity must be taken, the sugar, alcohol, acidity, total solids and mineral matter estimated in accordance with the processes elsewhere in this work so frequently described.

The only special examinations which would have to be made are those for the detection of alkalies, alkaline earths and lead in the ash.

In the first place, the weight of the ash would, in many cases, afford tolerably conclusive evidence of the addition of some mineral matter, while an estimation of the alkalinity of the ash would afford further evidence in the same direction. But for the identification of the particular substance added we must search for soda, lime, and lead by the methods which have been already given. The details of the process for the estimation of lead will be found fully set forth in the articles on 'Water' and 'Vinegar.'

CHAPTER XLV.

WINE AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any added substance or liquid not the product of the grape, including red colouring matters, but excepting alcohol or spirit, which must not be added so as to raise the strength of the wine beyond 13 per cent. of absolute alcohol by weight, equal to 15·8 per cent. by volume, or 28·1 per cent. of proof spirit.

Any added mineral substance, including the alkaline carbonates, and sulphate of potash, which must not exceed eight grains per bottle of one-sixth of a gallon; also lead.

We propose to treat the subject of Wine and its adulterations principally under the following heads: 1st, the manufacture of wine; 2nd, its composition; 3rd, its analysis; 4th, its adulteration; and 5th, the detection of its adulterations.

The Manufacture of Wine.

The ripe grapes, after being carefully picked, and sometimes freed from damaged or unripe berries, are crushed and pressed, the juice in the case of white grapes being usually freed from stalks and husks; it is then put into casks placed in a cellar or other cool situation, where it undergoes fermentation. In the case of black grapes the husks and stalks are not removed, but are allowed to ferment together with the juice. The wine is next drawn off the residue or murk, which is pressed, and the wine thus obtained added to that first drawn off from the barrel. With regard to the removal of the stalks there is, however, no invariable rule. Messrs. Thudichum and Dupré write:—'Practically, in the case of white wines, the stalks are never separated from the grapes; in some cases of light wines which incline to be viscous it is even advantageous to leave the stalks in prolonged contact with the murk. But this is exceptional, inasmuch as the murk of white grapes is, as a rule, pressed immediately, and not left in contact with the must for any length of time.' With most black grapes the case is different, because they have to remain in contact with the juice for a long time during fermentation, and in some cases, if the stalks are left in, a hard wine is produced, which it will take years to soften.

It is essential, if pure and natural wines are required, that the grapes should be thoroughly ripe. In the Sauterne district, according to Drs. Thudichum and Dupré, 'the best berries of every bunch are cut out at intervals and carried to the press; and an entire harvest of a vineyard consists of several, up to eleven, separate gatherings of all that has attained the highest state of ripeness.' In the finest situations of the Rheingau the grapes are not collected until the rains or frosts of the autumn necessitate the vintage. At Coudray, as at Tokay, the best wines are made from the grapes which have been longest on the vine.

Although ripeness is essential to the production of the best white wines, in the case of the red wines quality is, to some extent, sacrificed to colour, and unripe fruit is chosen. 'Consequently the highest quality of the wine is abandoned in favour of a conventional dye; and the unripe wine has to remain years in barrels and bottles before it acquires those properties which fit it for use.'—*Thudichum and Dupré.*

Again, champagne grapes are not permitted to attain to the highest maturity, because it is desired that such wines should be of as pale a colour as possible.

Composition of the Grapes.

Several varieties of *grapes* have been subjected to analysis, with the following results:—

	Fresenius. Ripe white Austrian grapes.	Schlieper. Kleinberger grapes.		Fresenius. Riesling grapes.	Fresenius.	
		Ripe.	Very ripe.	Very ripe.	Johannis-berg grapes.	Ass-mann haüse grape
Glucose	13·8	10·6	13·5	15·1	19·2	17·3
Tartaric acid . .	1·11	0·92	0·78	0·56	0·74	0·84
Albuminoid substance	0·8	0·6	4·1	3·4	3·0	
Pectin, gum, fat, &c.	0·5	0·2				
Ash	0·36	0·38				
Soluble portion . .	16·57	12·9	18·38	19·06	22·94	
Water	79·80	84·9	76·3	74·4		
Skins, stones, and cellulose . . .	2·6	1·8				
Pectose	0·9	0·7				
Ash	0·11	0·08				
Insoluble portion .	3·61	2·58	5·66	6·52		
	99·98	100·18	100·34	99·98		

Composition of the Juice or Must.

The *juice* or must resembles, of course, to a considerable extent, the grapes themselves.

The principal organic substances which enter into the composition of the juice of ripe grapes are *sugar, albumen, gluten, gum* or *vegetable mucus, tannin* and *colouring matter,* the tannin being derived mainly from the stalks, stones, and husks of the grapes, minute quantities of *fat* and *wax* from the husks, as well as much fat from the stones. The husks of white grapes gradually become brown, as we see in raisins, this change being due to the conversion of a part of the tannin into an insoluble substance, named *apothema* by Berzelius. The juice of grapes free from stalks, stones, and husks, contains scarcely any tannin.

The principal saline and mineral substances present in grape juice are *free tartaric* and *malic acids*, *tartrate of potash*, *tartrate* and *malate of lime*, *sulphate of potash*, *chloride of sodium*, *phosphates of lime* and *magnesia*, *manganese*, *iron* and *silicic acid*. The malic acid occurs in largest proportion in unripe grapes.

Before proceeding to make wine from grapes, it is very important to ascertain the amount of fruit sugar present in the juice or *must*. This object is simply effected by taking the weight or specific gravity of the must, for which purpose various contrivances have been adopted; but the instrument in general use has been termed a *glucometer*. This may be so graduated that each degree shall indicate a percentage of sugar; or it may be so arranged as to indicate by one degree of its scale a quantity of fruit sugar which after fermentation would yield a volume per cent. of absolute alcohol, or about '1,500 grammes of sugar per hectolitre of must.'

Where the amount of sugar present is determined solely from the gravity, a deduction or allowance has to be made of from one-tenth to one-fifteenth of the total solids indicated, on account of the presence of other constituents of the juice.

'In the north and centre of France must will seldom show more than 15°; but in the hottest regions of the south, in parts of Spain, Italy, Cyprus, Madeira, must is produced which shows up to 24° of the French glucometer.'—*Thudichum and Dupré*. This higher amount is not all converted into alcohol, because fermentation ceases in a liquor containing more than 16 per cent. of alcohol by volume, equal to 28 per cent. of proof spirit.

Sometimes, when the must is very sweet, and it is not desired to produce sweet wines, it is diluted with water. In other cases, when the must is very poor, sugar is added; practices which are both to be condemned, since the resulting wine must of necessity be of an inferior quality, and deficient in the special wine-constituents and characteristics, in tartaric and malic acids, phosphoric acid, potash, and the various ethers, acids, and compounds which impart flavour and bouquet to wine.

In the mashing of the grapes, care must be taken not to crush the stalks and the pips; in some cases the mashing is effected by the treading of the feet of men, but now usually, and happily, by machines or mills.

In the preparation of white wines the must is separated as much as possible before the murk is pressed; in the case of red wines, the juice, which flows off the platform or press, together with all the husks on the press and the stalks, if they have not been romoved, are put into the fermenting vats. When the fermentation is complete, the wine is drawn off, and the murk is put into the press, and the wine flowing from it added to that which is first drawn off.

When the wine has completed its fermentation, which it takes a long time to do, and has become clear, it is 'racked' off from the yeast and other impurities, and the comparatively clear wine is put into a clean cask.

But, as it is not yet quite clear and bright, it is next 'fined,' an operation which is usually effected by means of isinglass. After remaining at rest for about six weeks, the wine is found clear and bright, and, being again racked, it generally remains so, and is then ready for sale in bulk or for bottling.

THE COMPOSITION OF WINE.

The principal changes which the must undergoes by fermentation and its consequent conversion into wine are the transformation of the greater part of the sugar into ethylic alcohol, the formation of various acids, including especially acetic acid, and ethers, and the elimination of some of the saline matters of the ash, particularly the tartrates and malates.

The Sugar of Wine.

Two descriptions or modifications of sugar occur in wine—namely, *grape* and *fruit* sugar. They both have the same atomic constitution, —namely, $C_6H_{12}O_6$.

Dextrose or Grape sugar crystallises in granular masses, which contain one atom of water of crystallisation, which they lose, however, at 60° C.; it is slightly soluble in alcohol, and scarcely at all in ether. One atom of grape sugar boiled with the well-known copper solution reduces 10 atoms of oxide of copper.

Fifteen grammes of grape sugar, dissolved so as to form 100 cc. of solution, turn the plane of polarisation in Mitscherlich's apparatus 16·8 degrees to the right.

Lævulose or Fruit sugar is uncrystallisable, soluble in alcohol, and slightly so in ether. It may be thus separated from grape sugar: the concentrated solution of the two sugars is treated with a slight excess of hydrate of lime; the mass formed is subjected to pressure, when the liquid compound of lime and grape sugar is pressed out, and the more solid lime and fruit sugar remain. The lime is then got rid of by means of oxalic acid. It acts in the same way with the copper solution as grape sugar, but it differs optically in turning the plane of polarisation to the left; 15 grammes, dissolved so as to form 100 cc. of solution, turn the plane of polarisation in Mitscherlich's apparatus 31·8 degrees to the left at a temperature of 15° C.

Cane sugar ($C_{12}H_{22}O_{11}$).—Now, when cane sugar is boiled with acids or subjected to the action of ferments, it is converted into a mixture of the two kinds or varieties of sugar previously described, the mixture being in this case distinguished by the term *invert* sugar ($C_6H_{12}O_6$).

Solutions of cane sugar turn the plane of polarised light to the right, 15 grammes of cane sugar, dissolved in water so as to form 100 cc. of solution, turn the plane of polarisation 20° to the right, the tube being 20 centimetres long, and the change from red to blue being the measure of rotation.

Invert sugar.—15 grammes of this sugar, dissolved so as to give 100 cc. of solution, turn the plane of polarisation in Mitscherlich's apparatus, at a temperature of 15° C., 7·8 degrees to the left.

Glycerin.

This substance should be found in all wine, since it is always formed during the fermentation of sugar, whether cane or grape; 100 parts of cane sugar, or 105·26 of grape sugar, yield 3·64 parts of glycerin; this should, therefore, be always present in wine, in the proportion of about one-fourteenth part of the alcohol.

Glycerin has the following atomic composition:—$C_3H_6O_3 = C_3H_5, H_3O_3$. Its chief source is fat, whether animal or vegetable, of which it is a constituent, being obtained from it by saponification or by superheated steam; the fat takes up three atoms of water, a fatty acid and glycerin being formed. By the action of yeast and water it is converted into *propionic acid.*

Alcohol.

Grape-sugar, fruit sugar, and cane sugar, under the influence of fermentation, become converted into alcohol and carbonic acid, as shown in the following formula:—

$$\overset{\text{Grape sugar.}}{C_6H_{42}O_6} = \overset{\text{Alcohol.}}{2C_2H_6O} + \overset{\text{Carbonic anhydride.}}{2CO_2}.$$

In addition to these, some other compounds are formed in small quantities, as glycerin and succinic acid.

Alcohol at 15° C. has a specific gravity of 0·7938, and it boils at 78·4° C.

The allied or homologous alcohol radicles are methyl (CH_3), propyl (C_3H_7), butyl (C_4H_9), amyl (C_5H_{11}), caproyl (C_6H_{13}), and these radicles form corresponding alcohols.

Again, from these alcohols, some of the hydrogen being removed by combination with oxygen, aldehyde and water may be formed thus:—

$$\overset{\text{Ethylic alcohol.}}{C_2H_6O + O} = \overset{\text{Ethylic aldehyde.}}{C_2H_4O} + \overset{\text{Water.}}{H_2O}.$$

Lastly, oxidising agents acting on aldehyde, the place of the abstracted hydrogen is supplied by oxygen, the result being the oxidised acetic acid, thus:—

$$\overset{\text{Ethylic aldehyde.}}{C_2H_3,HO + O} = \overset{\text{Acetic acid.}}{C_2H_3O,HO}.$$

'Each primary alcohol has therefore a corresponding aldehyde and an acid. Only one primary ethylic and propylic alcohol existing there is, of course, only one corresponding aldehyde and acid. The higher alcohols, however, may give rise to an aldehyde and an acid for each of the isomeric primary alcohols possible. The compounds mentioned in the foregoing summary are either found in wine as a rule, or may be found under certain circumstances free or in combination. The radicle methyl occurs in trimethylamine, a strong base of the ammonia type present in many wines. The alcohol corresponding to this radicle, termed methylic alcohol or wood spirit, is not found in wine or any other fermented liquid. Of the remaining alcohols we have in wine besides the ethylic, which greatly predominates, propylic, butylic, amylic and caproic. All the alcohols of this class in wine, and in all other fermented liquids, are primary ones, and generally, though not always, normal. Of the several aldehydes, the ethylic and the propylic are now and then found in wines. Of the acids we find formic, related to methylic alcohol as acetic acid, a normal ingredient of wine, is to ethylic alcohol. Of propylic alcohol we may not only have the aldehyde, but also the acid, propionic acid. And of each of the higher members of the alcohol series we may have not only one but several primary forms, and of these forms the respective aldehydes and corresponding acids. Lastly, we may have the compound ethers of all those alcohols and acids formed with the acid corresponding to their series, as well as compound ethers of all those alcohols with the other acids of the wine.'—*Thudichum and Dupré.*

The presence of *acet-aldehyde* in a wine may be recognised by its very peculiar smell and flavour. If the wine be neutralised and distilled, the aldehyde will readily pass over, and may be distinguished by its smell, by its reducing action on salts of silver, and its ready conversion into acetic acid.

The Acids of Wine.

Of these some exist in the grape itself, while others result from the fermentation; the former consist of tartaric, malic, and tannic acids, the latter of acetic, formic, succinic, and carbonic acids; besides which wines usually contain minute quantities of some of the fatty acids, as œnanthic, propionic, and butyric acids.

Of *tartaric acid* two varieties are met with in wine—ordinary tartaric acid, termed, from its action on polarised light, dextro-tartaric; and levo-tartaric acid, which turns the plane to the left. *Racemic acid* also occurs in wine; this differs but little from tartaric acid, and is sometimes called para-tartaric acid.

These acids are all bibasic acids, forming both acid and neutral saslt.

Tartaric acid may be prepared artificially, as by the action of dilute nitric acid on sugar of milk and gum.

The tartaric acid and alcohol combine slowly in wine to form tartaric ether.

Lævo-tartaric acid does not exist in wine in the free state, but in combination with ordinary tartaric acid, forming together racemic acid, which, in the crystallised state, has the composition $C_4H_6O_6 + H_2O$. If strong solutions of the dextro- and lævo-tartaric acids are mixed, racemic acid is formed

Dextro-tartaric or ordinary tartaric acid, $C_4H_6O_6$, may be thus prepared and extracted from crude cream of tartar. The salt is decomposed by boiling with chalk, when a precipitate of tartrate of calcium is produced, neutral tartrate of potassium remaining in solution. This is then mixed with chloride of calcium, when a second quantity of tartrate of calcium is formed and precipitated. The tartrate of calcium is then decomposed with dilute sulphuric acid; the insoluble sulphate of lime is removed, and the solution of tartaric acid is evaporated until it crystallises.

The crystals belong to the oblique prismatic system, are unsymmetrical by reason of their hemihedral faces, and they do not contain any water of crystallisation. They dissolve readily in water, requiring little more than half their weight of cold, and still less of boiling water; they are also soluble in alcohol, but insoluble in ether; the solution turns the plane of polarisation to the right.

Malic acid ($C_4H_6O_5$) occurs in considerable amount in the juice of the grape, and, according to some, in wine also.

Like tartaric acid, it is bibasic, and forms acid and neutral salts and ethers.

Malic acid crystallises with difficulty in masses of radiating needle-like crystals; they are very deliquescent, soluble in water and alcohol, but very slightly so in ether. Its solution turns the plane of polarised light to the left.

The neutral and acid potash salts are soluble in water, alcohol, and a mixture of alcohol and ether; and hence a means is afforded of the separation of this acid from tartaric acid. The lime salt is also soluble in water, but is thrown down by prolonged boiling; alcohol likewise precipitates it from its aqueous solution.

Before the appearance of sugar in grapes malates predominate; afterwards, as the grapes ripen, the tartrates; the unripe grapes are, of course, much more acid than the ripe; this diminution of acid is in part apparent only, since the taste of the acid is covered and concealed by the sugar; and since, also, the grapes increase greatly in weight during growth. It has been surmised by some that part of the acid is, as formed, gradually converted into fruit sugar; but this has not been established, and it is more probable that the action of the acid in the production of sugar is analogous to that of dilute sulphuric acid on starch or dextrin.

Succinic acid ($C_4H_6O_4$), also bibasic, is always present in wine in minute quantity, being produced by the fermentation of grape sugar and the decomposition of malic acid. It may be prepared in quantity from amber by distillation, or from the fermentation of a mixture of one part of malate of lime, three of water, and one-twelfth of cheese.

According to Thudichum and Dupré, one litre of wine contains from 1 to 1·5 gramme of succinic acid.

Malic, tartaric, and succinic acids are convertible into each other; thus, tartaric acid heated with hydrochloric acid is reduced first to malic and then to succinic acid, while succinic acid by oxidation may be converted into malic and tartaric acids.

Succinic acid.	Malic acid.	Tartaric acid.
$C_4H_6O_4$	$C_4H_6O_5$	$C_4H_6O_6$

Furthermore, tartaric acid may be transformed into grape sugar, which may, in its turn, under the action of oxidising agents, be made to yield tartaric acid.

Acetic acid ($C_2H_4O_2$) is formed in wine principally by the oxidation of the alcohol. The stages of the process are—first, the abstraction of two atoms of hydrogen from the alcohol, water and aldehyde being formed; and second, the conversion of the aldehyde by the absorption of one atom of oxygen into acetic acid, thus:

$$\underset{\text{Alcohol.}}{C_2H_6O + O} = \underset{\text{Aldehyde.}}{C_2H_4O} + H_2O$$

$$\underset{\text{Aldehyde.}}{C_2H_4O + O} = \underset{\text{Acetic acid.}}{C_2H_4O_2}$$

Now, for the conversion of alcohol into acetic acid, four things are necessary—that the solution of alcohol be weak; that an albuminous matter to act as a ferment be present; that the liquid have an acid reaction; and that it be freely exposed to the air. Under these conditions the acetous fermentation takes place, and the vinegar fungus begins to develop, by the action of which the alcohol is rapidly converted into acetic acid.

But if oxygen be largely supplied, as when alcohol in weak solution is poured over wood shavings or birch twigs, it may be converted into acetic acid without the intervention of either albuminous matter or vinegar fungus or plant, as it is termed.

'In all moderately warm countries it requires but slight attention to prevent an excessive production of acetic acid, and in the wines produced there the quantity usually ranges from between 0·5 to 1·5 per 1,000 parts of wine. In warm countries and seasons, however, and in all cases in which the skins are allowed to ferment with the must, great care is requisite to prevent the formation of vinegar; and frequently the fermentation of the must has to be stopped by the addition of alcohol. It has been stated that the addition of acetic acid or vinegar to wine considerably favours the growth of the mycoderma; and as a parallel to this it is found that the rapidity with which wine is converted into vinegar increases to a certain extent with the increasing amount of acetic acid.'—*Thudichum and Dupré.*

The highest amount of acetic acid found by Thudichum in thirty samples of Rhine and other German wines amounted to 1·78 per 1,000 and the lowest to 0·36, but in seven samples of Greek wines the acid varied between 1·53 and 3·69 per 1,000 parts. In good sound wines the free acid ranges from 0·3 to 0·7 per cent., and of the total acidity not more than about 0·15 per cent. should be due to volatile acid. Acetic acid is monobasic, and forms but one class of salts and of ethers.

Lastly, it should be added that nearly the whole of the volatile acid of wine consists of acetic acid, and for all practical purposes may be estimated as such, and the fixed acids as tartaric acid.

The Fatty Acids.

These consist of the following: *acetic, formic, propionic, butyric, valerianic, caproic, œnanthylic, caprylic, pelargonic* and *melissic acids.* These acids run parallel to the ethylic series of alcohols, from which they may be derived, each acid differing from its corresponding alcohol in containing two atoms of hydrogen less and one atom of oxygen more.

The chief acid of this class besides acetic acid which has with certainty been detected in wine itself is *formic acid*, but the others have been, for the most part, found in the fusel oil obtained from wine.

Œnanthic Acid.

This acid $C_{14}H_{26}O_3$ has been discovered by Liebig in the ether to which the characteristic odour of wine is due. Thudichum and Dupré give the following process for obtaining it. Œnanthic ether is boiled with a solution of caustic potash, whereby alcohol is driven off and œnanthate of potassium remains; when all the alcohol has been driven off, the solution is acidified with dilute sulphuric acid, the oil is liberated, and after being thoroughly washed may be dried *in vacuo* over oil of vitriol.

Tannic Acid.

The juice of the pulp of grapes is free from tannin, but if in it the stalks or stones be allowed to ferment, the resultant wine will be found to contain more or less tannin; but it is in the red wines, and especially in the new red wines, that the most tannin is met with.

The tannin of wine is characterised by its affinity for albumen and gelatin, forming with it insoluble substances. Again, persalts of iron and acetate of potash give rise to a bluish-black coloration or precipitate. Sometimes part of the tannin met with in wine is derived from the oak casks in which it is kept.

Exposed freely to the air, tannin yields by decomposition glucose and gallic acid; but as wine cannot be freely exposed to the oxygen of the air, the latter acid is but rarely if ever found in wine. It also furnishes by oxidation a brown humus-like insoluble substance, termed by Berzelius, apothema. This substance is not quite insoluble in wine enough remains to colour it yellow, and in old port wine this colour alone remains, the red colouring matter having become precipitated with the tannin and albumen, all combining together with tartrates of potash and lime to form the crust of old port and other strong-bodied red wines. In new wines the whole of the colouring matter is thrown down, and the wine is left nearly colourless. It is only in the aged wines that the tawny or yellow colour is seen. This yellow colouring matter is the oxidised tannin of wine.

Tannin, by reason of its affinity for albumen, prevents that substance in wine from undergoing further change, and thus assists greatly in the preservation of the wine.

The Ethers of Wine.

These are divisible into the volatile and the fixed. The principal volatile ether of wine is the aceto-ethylic ether or acetate of ethyl ($C_4H_8O_2$), which is formed when ethylic alcohol and acetic acid are brought together; the weaker the solution of alcohol and acid the smaller will be the quantity of the ether formed. As this ether is produced in wine but slowly, its amount in a wine of good quality is to some extent a measure of age.

Other volatile ethers found in minute quantities in wine, and especially in old wine, are aceto-propylic, butyric, amylic, and caprylic ethers. These are formed by the union of the acetic acid with the several alcohol radicles.

Then, again, the fatty acids form with the several alcohols, ethers, as butyro-ethylic ether, caprylo-ethylic, capro-ethylic, and pelargo-ethylic ethers. In wine these acids probably usually combine with the more abundant ethylic alcohol. These ethers possess highly characteristic aromas, mostly of fruits; butyric and caprylic ethers have the smell of pineapples, caproic ether of melons, and to pelargonic acid is due probably, according to Thudichum, a portion of the characteristic wine flavour.

Œnanthic Ether.

Forty thousand parts of wine are said to yield one part of this oily ether, which passes over only towards the completion of the distillation.

Possessing a very strong vinous smell, it is to its presence that the characteristic smell of wine is mainly due.

Tartaric Ether.

Tartro-ethylic ether ($C_6H_{10}O_6$) is also met with in wine.

'By the influence upon each other of the alcohols and acids shown to be present in wine a considerable number of compound ethers may be produced. For, supposing five acids and five alcohols to be present, they might produce twenty-five compound ethers, some or all of which might be present, and contribute their share to the flavour, such flavour altering as one or the other ether predominates. All these ethers occur in wine in extremely minute quantity only, and almost entirely evade ordinary analysis. However, in the manufacture of brandy enormous quantities of wine are distilled, and a considerable amount of so-called fusel oil obtained, in which a number of the above-named volatile acids and ethers, as well as several alcohols, have been detected. In order to completely study the subject, it would be necessary not only to collect those fusel oils, which generally constitute the parts distilling over last, but to submit the brandy itself to oft-repeated fractional distillation, so as to obtain the more volatile ethers as well.'—*Thudichum and Dupré.*

According to Berthelot, the amount of the ethers found in wine increases with the quantities of alcohol and acid, and stands in a nearly constant ratio therewith. On these data he has constructed a formula for the calculation of the ethers independent of their direct determination. This formula will be found stated elsewhere in this article, the results afforded by its use being found to correspond pretty closely with those obtained by actual analysis.

The ethers of wine being of two kinds, fixed and volatile, though principally the latter, and the fixed acids which enter into their composition existing ready-formed in the must and even grapes, it follows that the fixed ethers are the first produced, and are to be found in comparatively young wine, whereas the volatile ethers, mainly acetic ether, are generated only gradually; so that the amount of volatile ethers, as a rule, affords a valuable indication of the age and maturity of a wine.

Messrs. Thudichum and Dupré state that 'the amount should gradually augment with age, until in from four to six years the maximum would be reached. If, then, a fresh amount of alcohol be added, and the wine fortified, etherification will begin afresh, and again reach a maximum after a number of years. On the other hand, a wine prepared artificially with addition of ethers, will probably at once have a maximum of ethers, or will even exceed this, and will then, instead of increasing in richness, remain stationary, or show a diminution of the ether with increasing age.'

The Bouquet of Wine.

The smell or bouquet of wine is of two kinds—general and special. That common to all good wines arises from certain volatile ethers which have already been particularised, and the principal of which is œnanthic ether.

Of the special constituents, some exist in certain kinds of grapes, as Muscatel and Isabella grapes; while others are generated 'partly out of substances already present in the grapes, and partly from matters formed during or after fermentation.' 'The first class are found in what are termed aromatic wines; the second in bouqueted wines. The substances characterising aromatic wines are found apparently in greater quantity with the increasing ripeness of the grape, and belong probably to the category of essential oils. On the other hand, the substances yielding the bouquet are sometimes contained in greater quantity in the unripe than in the ripe grape. Their chemical nature is but little understood. Partly, no doubt, they consist of a mixture of compound ethers, formed by the middle members of the fatty acid series. These acids originate in the oxidation of albuminous substances as well as in the oxidation of some of the higher members of the series or their fats. The more important constituents of true bouquet, however, seem to be of a different nature. The fruit-blossoms, or other parts of certain plants, when submitted to fermentation, produce a small quantity of essential oil, termed ferment oil, which possesses a characteristic smell, not unfrequently resembling the bouquet of certain kinds of wine. Thus, the flowers of the elder, when allowed to ferment with the must, impart to it the aroma of Muscatel grapes; whilst the flowers of the vine itself under these circumstances produce the Rhine wine bouquet.'—*Thudichum and Dupré.*

The Colouring Matters of Wine.

White wines.—Some of the white wines contain but little colouring matter, as Champagne; others, as most sherries, more. The colour of white wines depends much upon the grapes from which they are made, especially their condition as to ripeness; and this colour usually increases with age, owing to the oxidation of some of the extractive matters of the wine, and in particular the tannin. Not unfrequently the colour of white wines is increased by the addition of a dark syrup. obtained by the evaporation of the juice of very ripe and dark coloured grapes; in other cases by the use of caramel or burnt sugar—an objectionable practice, and one very injurious to the flavour of the wine.

Red wines.—The various tints and depths of colour of red wines are due sometimes to the colouring matter contained in the pulp of some descriptions of grapes, but chiefly to that present in the skins of the fruit.

The colouring matter of the pulp of certain grapes has hitherto been but little studied; it is, however, distinguished by its solubility, and is said in this respect to agree with that of elder-berries and black currants. In France and Spain a vine is much cultivated, called the 'Teinturier,' and the grapes of which produce a wine of a deep colour, much employed for increasing the colour of other wines.

The colouring matter of the skins of red grapes is, in its natural state, insoluble; and hence the two kinds of colouring matter might be separated in the juice of the grape, but unfortunately not in the wine itself, and which, not unfrequently, contains both descriptions of colouring matter. Port wine very generally contains some of the colouring matter of the 'Teinturier.'

The colouring matter or powder obtained from a red wine by Mulder's process, described hereafter, has the following properties and reactions; it is of a bluish-black colour, and is quite insoluble in water, alcohol, ether, chloroform, sulphide of carbon, olive and turpentine oils: with alcohol containing a trace of acetic acid it yields a beautiful blue liquid; with more acid it becomes red; with alcohol and tartaric acid it also turns red, although it is only soluble in small quantities, and after being dried it requires some hours to dissolve.

If the acid be just neutralised with ammonia the solution becomes blue; the same change occurs on the cautious addition of potash, soda, or lime; but even then a fresh addition of acid will restore the red colour.

With basic and neutral acetate of lead the colouring matter forms a blue precipitate, consisting of oxide of lead and colouring matter, which therefore, in this case, replaces an acid.

If more ammonia be added to the red solution of the colouring matter in alcohol and tartaric acid than is necessary to neutralise the acid, the colour which was before blue becomes green; if the ammonia be allowed to act for a little time, or more be added, it becomes brown, and the red colour cannot now be restored by means of an acid. The other alkalies possess the same property of decomposing the blue colouring matter.

Although this colouring matter is thus easily destroyed by alkalies, it is comparatively unaffected by acids, even by strong sulphuric acid. Chlorine causes, like the alkalies, the colouring matter to become brown, while excess of chlorine causes the brown substance to become bright yellow.

When to its solution in alcohol and tartaric acid nitrate of silver is added, the solution becomes deeper red; with mercuric chloride, paler; by nitrate of mercury it is unaltered; chloride of tin makes it darker red, and slightly violet; nitrate of lead, brighter red; the precipitates of certain acid salts are colourless; acetate of alumina gives it a violet hue, very much like the colour of wine.

These several reactions explain the changes of colour which wine undergoes, according as it is but little or strongly acid. Unfortunately, there do not appear to be any peculiarities in these reactions whereby the colouring matter of the grape may be distinguished from that of other red vegetable colouring matters, as those of logwood, cherries, or the elderberry.

Mulder's experiments were made upon colouring matter obtained from a French red wine, but he states that the colouring matter of Burgundy, Bordeaux, and port exhibits precisely the same properties. In port wine and in other wines which have been cellared, and which were originally of a dark colour, two colouring matters may be detected—the one the ordinary red colouring matter, the other yellow, this being the product of the oxidation of the tannic acid. If port wine be precipitated with acetate of lead a dirty deposit is obtained; if this be washed the liquid which flows from it is colourless; if after washing it be suspended in water and sulphuretted hydrogen be passed through it, the liquid will now be tinged of a pale yellow colour. The sulphide of lead is found to contain both the red and yellow colouring matters; if it be treated with warm alcohol and tartaric acid a tincture of a port-wine colour is obtained, redder if the wine be young, and browner if it be old, it now containing the two colouring matters. If this liquid, which contains both tartaric acid and alcohol, be digested with carbonate of lime, evaporated to dryness on a water-bath, and treated with water till the last trace of acid disappears, boiled with water and filtered, the oxidised tannin is obtained as a brown liquid, while the red colouring matter is retained by the lime, from which it can be extracted by means of alcohol and tartaric acid.

In the crust of port wine the tannin is in an insoluble state; extracted with alcohol and tartaric acid the crust gives a yellow tincture like very old port wine, but, if this be treated with chalk, boiling produces no brown solution owing to the tannin having been rendered insoluble.

Ammonia.

A very minute quantity of ammonia is usually present in wine, which, according to Mulder, is not contained in the grape, but is due to the action of the ferment on the albuminous constituents of the juice. Of the ammonia thus formed part is precipitated during fermentation, as phosphate of ammonia and magnesia.

Thudichum and Dupré found, by Wanklyn and Chapman's process, the following quantities of ammonia in the wines named below:—

Ingelheimer, red	0·0051	per cent.
Port, 1851	0·0046	„
Sherry, 30 years in bottle	0·0073	„
Madeira	0·0021	„
Niersteiner	0·0021	„
Natural port	0·0019	„
Port, 1865	0·0012	„

Albuminous Matter.

The unfermented juice of grapes contains much albuminous matter. Part of this forms the ferment of wine, which is absorbed by the yeast, and is deposited in an insoluble form during fermentation; but a small quantity is still invariably contained in all wine, as will be seen hereafter.

Properly fermented wines contain but little nitrogenous matter; imperfectly fermented wines more, and these are consequently liable to further fermentation, while red wines contain the most, especially when young, the tannic acid preserving it from further change. In course of time, however, much of this albumen becomes precipitated with the tannin, and helps to form the crust of red wines.

In considering the question of the presence of albuminous matters in wine, we must remember that albumen is precipitated by alcohol, even when much diluted, so that as a rule the stronger the wine the less albumen it will contain. Again, the tannic acid forms an insoluble compound with albumen, thus preserving it and the wine as well from further change; and in time, as in red wines, this becomes in part deposited; but, on the other hand, it must not be forgotten that albumen is soluble in tartaric acid, even in the presence of the alcohol and tannin of wine. In weak alcoholic liquids, as weak wine or beer much albumen may be present, because in these cases the large quantity of water present keeps it in solution. Much albumen, according to Mulder, is also present in champagne, causing it, after it has been poured out a little time, to become thick.

The Mineral Constituents of the Grape.

The different proportions of the inorganic constituents of the ash of grapes and of their juice must doubtless exert an influence on the quality of the wine, and are important in the determination of its purity, so that it becomes of consequence to ascertain of what these consist, and in what quantities they are present.

Berthier gives the percentage composition of the ash of the *entire grapes*, known under the name of Gamay, collected at Nemours in 1850, as follows:—

Sulphate of potash	5·0
Chloride of potassium	2·7
Carbonated alkali	44·4
Carbonate of lime	10·5
Carbonate of magnesia	12·5
Phosphate of lime	23·5
Silicic acid	1·4
	100·0

Boussingault gives the following as the composition of the ash of must, and of a litre of wine, made from the same must:—

	Ash of must, per cent.	Ash of litre of wine in grammes.
Potash	36·9	0·842
Soda	0·4	—
Lime	10·7	0·092
Magnesia	2·2	0·172
Oxide of iron and alumina	3·4	—
Phosphoric acid	10·7	0·412
Sulphuric acid	5·4	0·096
Chlorine	0·4	traces.
Carbonic acid	12·4	0·250
Sand and silica	15·3	0·006
Loss	2·2	—
	100·00	1·870= 0·19 per cent.

Lastly Crasso's analyses of the ash of the must of purple and white grapes, of the skins and of the stones, are shown in the subjoined table:—

1. Must from unripe purple grapes of the small Burgundy or black Clavners (Metzger).
2. Must from ripe purple grapes, small Burgundy or black Clavners (Metzger).
3. Must from ditto, but from a different place.
4. Must from ripe white grapes, Schönfeilners or green Sylvaners (Babo and Metzger).
5. Purple skins from No. 1.

6. White skins from No. 4.
7. Stones from No. 1.
8. Stones from No. 4. All in 100 parts.

	1.	2.	3.	4.	5.	6.	7.	8.
Potash . . .	66·33	65·04	71·85	62·74	41·65	46·89	27·89	29·45
Soda . . .	0·33	0·42	1·20	2·66	2·13	1·62	—	—
Lime . . .	5·20	3·37	3·39	5·11	20·31	21·73	32·18	35·57
Magnesia . .	3·27	4·74	3·97	3·95	6·02	4·45	8·53	8·51
Oxide of manganese	0·82	0·75	0·10	0·30	0·76	0·51	0·35	0·45
Iron . . .	0·73	0·43	0·09	0·40	2·11	1·97	0·45	0·65
Sulphuric acid .	5·19	5·54	3·65	4·89	3·48	3·88	2·40	2·61
Chlorine . .	0·74	1·03	0·47	0·70	0·49	0·71	0·27	0·35
Silica . . .	1·99	2·10	1·19	2·18	3·46	2·57	0·95	1·27
Phosphoric acid .	15·38	16·59	14·07	17·04	19·57	15·66	27·00	21·05

From the foregoing analyses of the ashes of grape-juice we are enabled to determine with some approach to accuracy the proportions of the several salts present in 100 parts of grape-juice, and these would stand as given below :—

Potash	0·251
Soda	0·011
Lime	0·020
Magnesia	0·016
Oxide of manganese	0·001
Iron	0·002
Sulphuric acid	0·019
Silica	0·009
Phosphoric acid	0·068
Total .	0·397

In 100 parts of Chasselas grapes Berthier found of ash, 0·364.

In 100 parts of Pinot Noir Burgundy, 0·468.

Crasso, in the juice of ripe grapes, found 0·326 of ash.

In unripe grapes, 0·371 of ash.

Messrs. Thudichum and Dupré found the skins, stalks, and stones to yield the following amounts of ash per cent. :—

		Soluble.	Insoluble.
Grape stalks	6·0 .	0·4 .	5·6
Opaque green grape	5·0 .	0·6 .	4·4
Transparent grape	2·7 .	0 5 .	2·2
Ripe grape	2·6 .	0·4 .	2·2
Skin of grape	4·8 .	0·3 .	4·5
Stones of grape	2·7 .	0·2 .	2·5
Grapes from Gamay vine at Nemours (Berthier)	4·20 .	2·25 .	1·98

We must not, however, expect to find in wine anything like the quantities above given, and for the following reason. As fermentation proceeds, and more and more alcohol is formed, the mixture, now less watery than at first, can no longer retain in solution the same quantities of many of the saline constituents it previously held dissolved; thus phosphate, tartrate, and, it is affirmed by Muller, sulphate of lime, are being continually precipitated, as also bitartrate of potash, or cream of tartar; and according to the same authority, 'sulphate of potash and tartrate of magnesia, or tartrate of potash and magnesia.' Young wine, therefore, contains less of the salts mentioned than grape-juice, and old wine in which a crust is formed a still smaller amount.

Braçonnot found the sediment which first forms in wine to have the following composition:—

Albuminous matter	21
Cream of tartar	61
Tartrate of lime	5
Phosphate of lime	6
Sulphate of lime	2
Alumina, wax-like fat, &c.	5
	100

Mineral Constituents of Wine.

The mineral constituents of wine present in the ash resemble, of course, closely those of the grape, and consist of carbonate of potassa and lime, with phosphate and sulphate of potash, chloride of potassium, chloride of sodium, phosphate of lime and magnesia, with iron, silica, and frequently manganese and alumina, the last usually having an extraneous source.

Of course the carbonates of the ash are derived from the incineration of the organic acids, as the tartaric and malic acids, and are not present as such in the wine.

If, however, the must of the wine has been plastered, or the wine subjected to the process of sulphuring, the tartrates and malates are diminished in part or entirely removed, tartrate and malate of lime being thrown down, and sulphate of potassa taking its place, so that wines which have been thus treated may contain little or even no carbonic acid, but an excess of sulphuric acid; and it is also often free from chlorides, for the same reason; these, though absent from the ash, are always present in the wine itself.

The *amount* of ash contained in unplastered wines will of course vary with the quality, that is to say, with the amount of grape-juice from which they have been manufactured, the ash increasing with the quantity of grape-juice originally employed. Thudichum states the variation in natural wines to be from 0·15 to 0·30 per cent., but in plastered wines the amount reaches to 0·50 per cent., and in wines, the acidity of which has been neutralised, the weight of the ash is often even greater.

For the amounts of ash furnished by different wines, the reader is referred to the following tables of averages of analyses of wine.

Averages of the Analyses of Wine.

No.	Description of Wine.	Specific Gravity.	Alcohol, by weight.	Fixed Acid, as Tartaric Acid.	Volatile Acid, as Acetic Acid.	Total Acid, as Tartaric Acid.	Real Tartaric Acid.	Residue found.	Residue calculated.
1	German white . . (Thudichum.)	993·5	9·98	·440	·217	·538	·12 41	1·337	2·180
2	French white . . (Thudichum.)	992·2	10·84	·435	·169	·634	·1020	1·257	1·894
3	French red . . . (Thudichum.)	999·8	10·44	·374	·137	·580	·1269	2·145	3·677
4	Hungarian red . . (Thudichum.)	992·5	10·81	·386	·191	·628	·1222	1·677	1·979
5	Hungarian white . . (Thudichum.)	991·6	10·23	·419	·179	·644	·0567	1·026	1·587
6	Hungarian . . . (Griffin.)	—	10·35	·49	·10	·62	—	5·53	—
7	Greek white . . . (Thudichum.)	1004·2	11·24	·377	·185	·710	·0599	6·567	8·719
8	White Greek . . (Griffin.)	—	10·45	·51	·19	·95	—	8·62	—
9	Greek red . . . (Griffin.)	—	9·82	·42	·17	·63	—	2·79	—
10	Australian white . . (Griffin.)	989·5	13·37	·336	·211	·602	·0525	1·639	1·938
11	Australian red . . (Griffin.)	1000·2	13·19	·371	·332	·783	·0700	4·055	5·048
12	Australian red . . (Hassall.)	992·4	12·12	·710	·140	·885	—	2·337	—
13	Australian white . . (Hassall.)	995·9	12·60	·790	·146	·992	—	2·020	—
14	So-called natural sherry (Thudichum.)	989·7	14·85	·292	·131	·454	—	1·188	1·901
15	Sherries . . . (Thudichum.)	993·9	17·28	·291	·149	·475	·0187	3·098	4·098
16	Sherries . . . (Hassall.)	992·9	17·89	·390	·055	·458	—	3·955	—
17	Sherries . . . (Griffin.)	—	16·91	·36	·11	·50	—	3·81	—
18	Dry sherries . . . (Hassall.)	988·0	16·98	·379	·045	·435	—	2·803	—
19	Sweetened sherries . (Hassall.)	994·1	18·43	·378	·055	·447	—	4·882	—
20	Deplastered sherries . (Hassall.)	989·5	14·32	·310	·069	·396	—	2·716	—
21	Hambro' sherries . . (Hassall.)	994·4	17·85	·275	·047	·334	—	5·352	—
22	Imitation sherry . . (Thudichum.)	996·0	16·48	·257	·111	·397	·0100	3·603	4·956
23	Madeira . . . (Hassall.)	1001·3	16·12	·528	·071	·610	—	6·167	—
24	Marsala . . . (Thudichum.)	999·5	16·38	·241	·117	·389	—	3·572	5·007
25	Port . . . . (Thudichum.)	999·5	17·73	·271	·122	·424	·0150	4·234	6·607
26	Ports . . . . (Griffin.)	—	19·22	·30	·07	·309	—	5 90	—
27	Ports . . . . (Hassall.)	992·2	12·08	·556	·048	·616	—	2·778	—

Averages of the Analyses of Wine—(continued).

Grape Sugar.	Bitartrate of Potash.	Ash.	Alkalinity, as Caustic Potash.	Phosphoric Acid.	Phosphoric Acid in soluble part of ash.	Alcohol in Ethers, fixed.	Alcohol in Ethers, volatile.	Alcohol found in Ethers, expressed in per cents. of Alcohol calculated in Ethers.	Sulphuric Acid.	Cane Sugar.	No.
·310	0·079	·182	·025	·031	·022	·0190	·0258	96·0	—	—	1
·088	—	·197	·024	·031	·015	·0147	·0232	65·7	—	—	2
2·255	0·081	·223	·044	·031	·016	·0184	·0230	79·2	—	—	3
—	·122	·192	·054	·035	·015	—	—	77·6	—	—	4
—	·047	·189	·025	·031	·017	·0174	·0272	73·8	—	—	5
3·20	—	·23	·07	—	—	—	—	—	—	—	6
6·171	—	·348	·47	·032	·019	·0304	·0214	80·5	—	—	7
7·04	—	·34	·09	—	—	—	—	—	—	—	8
none.	—	·25	·09	—	—	—	—	—	—	—	9
·183	—	·234	·031	·012	·012	·0169	·0389	83·5	—	—	10
2·642	—	·266	·038	·024	·015	·0154	·0379	72·6	—	—	11
·076	·058	·253	·018	·035	—	—	—	—	—	—	12
·042	·087	·188	·081	·066	—	—	—	—	—	—	13
·119	—	·481	·009	·026	—	—	—	—	—	—	14
1·796	—	·529	·012	·022	·016	·0279	·0363	88·7	—	—	15
2·043	—	·437	·012	·023	—	—	—	—	·141	—	16
1·81	—	·38	·06	—	—	—	—	—	—	—	17
9·34	—	·567	·027	·022	—	—	—	—	·136	—	18
1·743	—	·448	·010	·022	—	—	—	—	·181	1·267	19
1·309	—	·268	·089	·026	—	—	—	—	·031	—	20
4·483	—	·171	·023	·014	—	—	—	—	·026	·869	21
2·230	—	·327	·028	·027	·015	—	—	—	—	—	22
3.000	—	·345	·049	·076	—	—	—	—	·133	—	23
2·750	—	·311	·021	·024	·010	·0294	·0202	99·5	—	—	24
3 332	—	·237	·67	·51	·024	·0303	·0239	86·9	—	—	25
4·38	—	·35	·10	—	—	—	—	—	—	—	26
·669	—	·247	·084	·035	—	—	—	—	·032	—	27

The Extractives.

The term extractives is sometimes applied to the whole of the residue obtained on the evaporation of a given quantity of wine; more correctly, however, it includes only certain undetermined matters, about which but little is known ; that is to say, to the residue left after the subtraction of all the known and easily determined non-volatile constituents, the sugar and mineral matters. Thus limited, however, the residue would still include certain well-known constituents, the determination of which is capable of being effected only with difficulty : as, tannin, dextrin, colouring matter, &c.

To some small extent the extractives proper afford indications whereby the quality and genuineness of wines may be determined; thus, in dry wines the extractive matters form a very considerable portion of the total solids; but in saccharine wines the amount is, of course, far less relatively to the sugar than in the former class of wines : while, lastly, in factitious wines, those made, as is some so-called sherry, from very weak wines, which consist chiefly of water, spirit, and sugar, the extractives are reduced to a minimum.

Total Solids.

The total solids of a wine consist of all those substances which remain after evaporation on a water-bath; as the sugar, gum, tannin, extractive matters proper, salts, &c. They do not, therefore, include the volatile constituents of a wine, the alcohol, ethers, or volatile acids, especially acetic acid.

AVERAGE COMPOSITION OF WINE.

Having thus treated separately of all the chief compounds of wine, we will now proceed to give the mean analyses of some of the principal varieties of wine calculated from the analyses of Thudichum and Dupré, Griffin, and from our own analyses. These will be found very useful for reference.

THE ANALYSIS OF WINE.

Estimation of Sugar.

There are two methods usually employed for the estimation of sugar in wine, namely, the chemical and the optical. We shall describe only the former method on the present occasion.

The chemical method consists in the employment of an alkaline solution of a salt of copper.

The copper solution is prepared as follows:—

Dissolve exactly 34·639 grm. of pure crystallised sulphate of copper, which has been perfectly freed from every trace of moisture by pressing between blotting-paper, in about 200 cc. of water. Dissolve in another vessel 173 grm. of pure Rochelle salt (tartrate of soda and potassa) in 480 cc. of pure solution of soda (spec. grav. 1·14), and pour the copper solution slowly into the second one, and dilute the dark blue clear solution to exactly 1,000 cc.; 10 cc. of this solution contain 0·34639 grm. of sulphate of copper, capable of decomposing 0·050 grm. of grape sugar. The solution should be kept in a dark place in well-corked bottles.

The wine should be diluted to such an extent that it contains about ½ per cent. of sugar; in most cases 50 cc. of wine and 200 cc. of water will be the right proportion; this varying, of course, with the wines of different countries. If the wine be of dark colour, as in the case of port, it must be decolorised by shaking it with powdered animal charcoal.

The estimation is effected in the following way:—Measure exactly 10 cc. of copper solution into a small flask or porcelain basin, dilute it with from 40 cc. to 50 cc. of water, heat nearly to boiling, and keep the liquid gently simmering. Add now from a burette, graduated in $\frac{1}{10}$ cc., the dilute wine in small quantities. The liquid appears, after addition of the first few drops, greenish, but gets gradually perfectly red. After a few minutes' heating, the precipitate, consisting of cuprous oxide, settles in most cases very easily, and the colour of the liquid can readily be observed. Continue adding the wine as long as the liquid appears blue. In this manner the point of saturation can be observed with sufficient accuracy, if the wine be of light colour; if not, a small quantity of the liquid should be filtered into a test-tube, and a drop or two of the wine added to it and boiled. If no more red precipitate or turbidity appears, the reaction is finished; but if a doubt is still entertained, and the point of the disappearance of the blue colour be uncertain, a drop of ferrocyanide of potassium and a few drops of acetic acid may be added to the liquid in the test-tube, when, if a brown precipitate or colour appears, it is manifest that there is still copper in solution. The quantity of wine used contains 0·05 grm. of grape sugar. Calculate for 100 parts of wine.

The same process is employed for the estimation of cane sugar after its conversion into glucose in the usual manner. Sometimes the quantity of sugar is estimated from the weight of the oxide of copper thrown down, 220·5 parts of the oxide corresponding to 100 parts of sugar. In this case the oxide should be collected on a weighed filter while the liquid is still hot. If the oxide be allowed to remain for any length of time in the cold solution, part of it will become dissolved, and thus the estimation will be rendered valueless. We have found that the boiling alkaline solution dissolves a very perceptible quantity of cellulose from the filter, and the results thus obtained are frequently quite inaccurate; hence it is safest in all cases to estimate the sugar volumetrically.

Other methods have been devised for the determination of sugar, as by its conversion into carbonic acid and alcohol, and the estimation of either the acid or the alcohol; but this method is never employed in the estimation of sugar in wine, and therefore it is unnecessary to enter into any description of it in this article on wine analysis.

Alcohol Tables.

Specific Gravity at 15·5° C.	Absolute Alcohol per cent. by weight.	Absolute Alcohol per cent. by volume.	Percentage of Proof Spirit.	Specific Gravity at 15·5° C.	Absolute Alcohol per cent. by weight.	Absolute Alcohol per cent. by volume.	Percentage of Proof Spirit.
·9942	3·20	4·00	7·02	·9897	5·96	7·42	13·02
1	3·26	4·07	7·16	6	6·02	7·50	13·15
0	3·32	4·14	7·29	5	6·09	7·58	13·30
·9939	3·37	4·21	7·40	4	6·15	7·66	13·43
8	3·43	4·28	7·53	3	6·22	7·75	13·59
7	3·49	4·36	7·66	2	6·29	7·83	13·74
6	3·55	4·43	7·79	1	6·35	7·91	13·87
5	3·61	4·50	7·92	0	6·42	8·00	14·02
4	3·67	4·57	8·05	·9889	6·49	8·08	14·17
3	3·73	4·64	8·18	8	6·55	8·17	14·30
2	3·78	4·71	8·29	7	6·62	8·25	14·45
1	3·84	4·78	8·42	6	6·69	8·33	14·60
0	3·90	4·86	8·55	5	6·75	8·42	14·73
·9929	3·96	4·93	8·68	4	6·82	8·50	14·88
8	4·02	5·00	8·81	3	6 89	8·58	15·03
7	4·08	5·08	8·94	2	6·95	8·66	15·16
6	4·14	5·15	9·07	1	7·02	8·75	15·31
5	4·20	5·23	9·20	0	7·09	8·83	15·47
4	4·27	5·31	9·36	·9879	7·16	8·91	15·62
3	4·33	5·38	9·49	8	7·23	9·00	15·77
2	4·39	5·46	9·62	7	7·30	9·08	15·92
1	4·45	5·54	9·75	6	7·37	9·17	16·07
0	4·51	5·62	9·88	5	7·43	9·25	16·20
·9919	4·57	5·69	10·01	4	7·50	9·33	16·35
8	4·64	5·77	10·16	3	7·57	9·42	16·50
7	4·70	5·83	10·29	2	7·64	9·50	16·65
6	4·76	5·92	10·42	1	7·71	9·58	16·80
5	4·82	6·00	10·55	0	7·78	9·66	16·95
4	4·88	6 08	10·68	·9869	7·85	9·75	17·10
3	4·94	6·15	10·81	8	7·92	9·83	17·26
2	5·01	6·23	10·96	7	7·99	9·91	17·41
1	5·07	6·31	11·09	6	8·06	10·00	17·56
0	5·13	6·38	11·22	5	8·13	10·08	17·71
·9909	5·20	6·46	11·38	4	8·20	10·17	17·86
8	5·26	6·54	11·51	3	8·27	10·25	18·01
7	5·32	6.62	11·64	2	8·34	10·33	18·16
6	5·39	6·69	11·79	1	8·41	10·42	18·31
5	5·45	6·77	11·92	0	8·48	10·50	18·46
4	5·51	6·85	12·05	·9859	8·55	10·58	18·61
3	5·58	6·92	12·20	8	8·62	10·66	18·76
2	5·64	7·00	12·33	7	8·70	10·75	18·93
1	5·70	7·08	12·46	6	8·77	10·83	19·08
0	5·77	7·17	12·61	5	8·84	10·91	19·23
·9899	5·83	7·25	12·74	4	8·91	11·00	19·38
8	5·85	7·33	12·87	3	8·98	11·09	19·54

Alcohol Tables.

Specific Gravity at 15·5° C.	Absolute Alcohol per cent. by weight.	Absolute Alcohol per cent. by volume.	Percentage of Proof Spirit.	Specific Gravity at 15·5° C.	Absolute Alcohol per cent. by weight.	Absolute Alcohol per cent. by volume.	Percentage of Proof Spirit.
·9852	9·05	11·18	19·69	·9807	12·62	15·36	27·31
1	9·12	11·27	19·84	6	12·69	15·45	27·48
0	9·20	11·36	20·01	5	12·77	15·55	27·64
·9849	9·27	11·45	20·16	4	12·85	15·64	27·80
8	9·34	11·55	20·31	3	12·92	15·73	27·97
7	9·41	11·64	20·46	2	13·00	15·82	28·13
6	9·49	11·73	20·63	1	13·08	15·91	28·29
5	9·56	11·82	20·78	0	13·15	16·00	28·46
4	9·63	11·91	20·93	·9799	13·23	16·10	28·62
3	9·70	12·00	21·08	8	13·31	16·20	28·79
2	9·78	12·09	21·25	7	13·39	16·30	28·95
1	9·85	12·18	21·40	6	13·46	16·40	29·11
0	9·92	12·27	21·55	5	13·54	16·50	29·29
·9839	9·99	12·36	21·70	4	13·62	16·60	29·44
8	10·07	12·45	21·87	3	13·69	16·70	29·61
7	10·16	12·55	22·07	2	13·77	16·80	29·77
6	10·26	12·64	22·27	1	13·85	16·90	29·93
5	10·35	12·73	22·47	0	13·92	17·00	30·10
4	10·44	12·82	22·67	·9789	14·00	17·10	30·26
3	10·54	12·91	22·87	8	14·08	17·20	30·45
2	10·63	13·00	23·07	7	14·17	17·30	30·64
1	10·72	13·09	23·27	6	14·25	17·40	30·84
0	10·81	13·18	23·47	5	14·33	17·50	31·03
·9829	10·91	13·27	23·67	4	14·42	17·60	31·22
8	11·00	13·36	23·87	3	14·50	17·70	31·41
7	11·08	13·45	24·04	2	14·58	17·80	31·60
6	11·15	13·55	24·20	1	14·66	17·90	31·79
5	11·23	13·64	24·36	0	14·75	18·00	31·99
4	11·31	13·73	24·52	·9779	14·83	18·10	32·18
3	11·39	13·82	24·68	8	14·91	18·20	32·38
2	11·46	13·91	24·84	7	15·00	18·30	32·56
1	11·54	14·00	25·01	6	15·08	18·40	32·73
0	11·62	14·10	25·17	5	15·17	18·50	32·91
·9819	11·69	14·20	25·34	4	15·25	18·60	33·08
8	11·77	14·30	25·50	3	15·33	18·70	33·26
7	11·85	14·40	25·66	2	15·42	18·80	33·43
6	11·92	14·50	25·83	1	15·50	18·90	33·61
5	12·00	14·60	26·00	0	15·58	19 00	33·78
4	12·08	14·70	26·16	·9769	15·66	19·10	33·96
3	12·15	14·80	26·33	8	15·75	19·20	34·14
2	12·23	14·90	26·49	7	15·83	19·30	34·32
1	12·31	15·00	26·66	6	15·91	19·40	34·50
0	12·39	15·09	26·82	5	16·00	19·50	34·66
·9809	12·46	15·18	26·98	4	16·08	19·60	34·82
8	12·54	15·27	27·15	3	16·17	19·70	34·97

Alcohol Tables.

Specific Gravity at 15·5° C.	Absolute Alcohol per cent. by weight.	Absolute Alcohol per cent. by volume.	Percentage of Proof Spirit.	Specific Gravity at 15·5° C.	Absolute Alcohol per cent. by weight.	Absolute Alcohol per cent. by volume.	Percentage of Proof Spirit.
·9762	16·25	19·80	35·14	·9717	19·91	24·20	42·73
1	16·33	19·90	35·30	6	20·00	24·30	42·90
0	16·42	20·00	35·46	5	20·08	24·40	43·07
·9759	16·50	20·10	35·62	4	20·17	24·50	43·25
8	16·58	20·20	35·77	3	20·25	24·60	43·42
7	16·66	20·30	35·95	2	20·33	24·70	43·60
6	16·75	20·40	36·11	1	20·42	24·80	43·77
5	16·83	20·50	36·27	0	20·50	24·90	43·94
4	16·91	20·60	36·43	·9709	20·58	25·00	44·12
3	17·00	20·70	36·61	8	20·66	25·09	44·29
2	17·08	20·80	36·78	7	20·75	25·18	44·46
1	17·17	20·90	36·96	6	20·83	25·27	44·63
0	17·25	21·00	37·13	5	20·91	25·36	44·81
·9749	17·33	21·10	37·31	4	21·00	25·45	44·99
8	17·42	21·20	37·48	3	21·08	25·54	45·15
7	17·50	21·30	37·66	2	21·15	25·64	45·31
6	17·58	21·40	37·83	1	21·23	25·73	45·47
5	17·66	21·50	38·01	0	21·31	25·82	45·63
4	17·75	21·60	38·18	·9699	21·38	25·91	45·79
3	17·83	21·70	38·36	8	21·46	26·00	45·95
2	17·91	21·80	38·53	7	21·54	26·10	46·11
1	18·00	21·90	38.71	6	21·62	26·20	46·27
0	18·08	22·00	38·87	5	21·69	26·30	46·43
·9739	18·15	22·09	39·03	4	21·77	26·40	46·59
8	18·23	22·18	39·19	3	21·85	26·50	46·76
7	18·31	22·27	89·35	2	21·91	26·60	46·92
6	18·38	22·36	39·51	1	22·00	26·70	47·07
5	18·46	22·45	39·67	0	22·08	26·80	47·23
4	18·54	22·54	39·83	·9689	22·15	26·90	47·39
3	18·62	22·64	40·00	8	22·23	27·00	47·55
2	18·69	22·73	40·16	7	22·31	27·09	47·71
1	18·77	22·82	40·32	6	23·38	27·18	47·87
0	18·85	22·91	40·48	5	22·46	27·27	48·03
·9729	18·92	23·00	40·64	4	22·54	27·36	48·19
8	19·00	23·10	40·81	3	22·62	27·45	48·35
7	19·08	23·20	40·98	2	22·69	27·55	48·51
6	19·17	23·30	41·16	1	22·77	27·64	48·67
5	19·25	23·40	41·33	0	22·85	27·73	48·83
4	19·33	23·50	41·51	·9679	22·91	27·82	48·99
3	19·42	23·60	41·68	8	23·00	27·91	49·15
2	19·50	23·70	41·85	7	23·08	28·00	49·51
1	19·58	23·80	42·03	6	23·15	28·09	49·47
0	19·66	23·90	42·20	5	23·23	28·18	49·63
·9719	19·75	24 00	42·38	4	23·31	28·27	49·78
8	19·83	24·10	42·55	3	23·38	28·36	49·94

Alcohol Tables.

Specific Gravity at 15·5° C.	Absolute Alcohol per cent. by weight.	Absolute Alcohol per cent. by volume.	Percentage of Proof Spirit.	Specific Gravity at 15·5° C.	Absolute Alcohol per cent. by weight.	Absolute Alcohol per cent. by volume.	Percentage of Proof Spirit.
.9672	23·46	28·45	50·10	0	24·38	29·55	52·01
1	23·54	28·55	50·25	·9659	24·46	29·64	52·16
0	23·62	28·64	50·41	8	24·54	29·73	52·32
·9669	23·69	28·73	50·57	7	24·62	29·82	52·48
8	23·77	28·82	50·73	6	24·69	29·91	52·64
7	23·85	28·91	50·89	5	24·77	30·00	52·80
6	23·91	29·00	51·05	4	24·85	30·08	52·96
5	24·00	29·09	51·21	3	24·91	30·17	53·12
4	24·08	29·18	51·37	2	25·00	30·25	53·28
3	24·15	29·27	51·53		Proof	Spirit.	
2	24·23	29·36	51·69	·91984	49·24	57·06	100
1	24·31	29·45	51·85				

Determination of Glycerin.

The following is the method of M. Pasteur for the determination of the glycerin of wine resulting from the transformation of a portion of the sugar consequent on fermentation:—

To half a litre of wine 40 grammes of animal charcoal are added; the mixture is to be frequently shaken, and after twenty-four hours the charcoal is separated by filtration. It is now to be well washed with cold water, and the filtrate is to be evaporated on a water-bath to 200 cc. It is then neutralised with milk of lime evaporated to dryness, and the residue treated with a mixture of two parts of ether and one of alcohol. This solution, which may contain fruit sugar, is evaporated in a water-bath, and lastly dried *in vacuo* over sulphuric acid, and finally weighed.

Estimation of Alcohol.

Numerous as the proposed methods for estimating alcohol are, there are but very few which give exact and easily obtainable results. The most important and generally employed method is based upon the fact that the specific gravity of a mixture of alcohol and water has a very close relation to the quantity of alcohol contained in it. Alcohol is lighter than water, the specific gravity of absolute alcohol being 0·792; and the specific gravity of a dilute alcohol lies between that number and 1·000, the specific gravity of the water. With very great care, tables have been constructed for estimating the specific gravities of mixtures of alcohol and water; so that, the gravity of an alcoholic liquid being given, the percentage of absolute alcohol contained in it can directly be seen from those tables.

The preceding tables are taken from Thudichum and Dupré's work before referred to.

The alcoholic liquid, the specific gravity of which is to be estimated, must of course be freed from the solid matters found in the wine, which is easily effected by simple distillation. Measure a certain quantity of wine, conveniently 100 cc., render it slightly alkaline by addition of caustic soda solution, in order to fix the volatile acids, add about one decigramme of pure tannin and 25 cc. of water, and boil the mixture till the distillate amounts to about 100 cc., or fill eventually up with water to the volume of the wine employed. All alcohol is now in the distillate, mixed with water, and only very small quantities of the different ethers, which give to the wine its flavour. It is not advisable to distil less than three-fourths of the volume of the wine, since the last traces of alcohol volatilise only with difficulty. Some authors distil no more than about one-half, or even less, which is decidedly too little. Having now obtained the alcoholic liquid, its specific gravity is to be estimated, which may be done in various ways, but most accurately by the use of the 'specific gravity bottle.' This is a little glass flask, holding about 20 to 40 cc., provided with a perforated glass stopper, or a small thermometer as stopper. The bottle must be first weighed, then filled with pure distilled water of 15·5° C. The difference between the two weights is of course the weight of the water contained in the bottle. The bottle is then rinsed out with the alcoholic liquid, the specific gravity of which is to be taken at a temperature of 15·5° C., and the weight determined. The weight of the alcohol, divided by that of the water, gives the specific gravity of the liquid at 15·5° C. The same process holds good for the determination of the specific gravity of all other liquids. A glance at the table given above shows the percentage of alcohol contained in the wine. It is most convenient to express the amount of alcohol in parts by weight in volumes of wine.

There are three cases which may occur:—

(I.) *The wine employed, and the distillate obtained, have been measured.*

1. Required percentage of alcohol by weight in weight of wine.—Multiply percentage by weight given in the tables by the specific gravity of the distillate, and divide by the specific gravity of the wine.

2. Required percentage of alcohol by weight in volume of wine.—Multiply percentage by weight of distillate by the specific gravity of distillate.

(II.) *The wine and the distillate have both been weighed.*

1. Required percentage of alcohol by volume in volume of wine.—Multiply percentage by volume of distillate by the specific gravity of the wine, and divide by the specific gravity of the distillate.

2. Required percentage of alcohol, by weight in volume of wine.—Multiply percentage by weight of distillate, by the specific gravity of the wine.

3. Required percentage of alcohol by weight in weight of wine.—These numbers are given in the tables.

(III.) *The wine has been measured, the distillate weighed.*—The percentage of alcohol is directly given by the alcohol tables.

Of other methods for the estimation of alcohol in wine we mention the following; but for a more elaborate description of them we must refer the reader to works specially treating of the subject.

Estimation founded upon the boiling-points of mixtures of alcohol and water.

Estimation founded upon the expansion of alcoholic liquids; and lastly, estimation founded upon the tension of the vapour of the liquid. Several ingenious apparatus have been constructed upon the above-mentioned principles.

These methods require the greatest possible care, and are very liable to error. With heavy wines the best process is that by distillation, and next, Balling's plan, which can be completed in the least time.

Estimation of Alcohol by conversion into Acetic Acid.

This method is only applicable to alcoholic liquids containing minute quantities of alcohol, where its determination with accuracy by the specific gravity test would be impossible. The alcohol is converted into acetic acid by heating it in a strong closed flask, with a mixture of a solution of bichromate of potash and sulphuric acid. The acetic acid formed by the oxidation of the alcohol is distilled over and estimated by means of standard soda solution in the usual way. Of course care must be taken to add sufficient bichromate to oxidise all alcohol present. One equivalent of alcohol, C_2H_6O, corresponds to one equivalent of acetic acid, $C_2H_4O_2$, or 46 parts alcohol are equal to 60 parts of acetic acid.

Determination of Alcohol by Specific Gravity of dealcoholised Wine.

If a measured quantity of wine be boiled down to about one-fourth of its bulk, and then filled up again with distilled water to the volume employed, the specific gravity of the liquid must of necessity be higher than the specific gravity of the original wine, since all alcohol has been driven away, and only the non-volatile constituents have been left. All these latter have a higher specific gravity than water; the specific gravity of their solution must, therefore, also be higher than the specific gravity of water. It has been proved by Balling and others, that the specific gravity of the dealcoholised wine gives pretty accurately the amount of total solids, if we consider the liquid to be a solution of pure cane sugar only, and the difference of the specific gravities will give us the amount of alcohol driven off by boiling. The amount of volatile ethers, aldehydes, &c., is so small as not to interfere practically with the accuracy of the determination.

The principle involved is, that the specific gravity of a dilute alcohol multiplied by the specific gravity of a solution of cane sugar gives the specific gravity of the mixed fluids; and the specific gravity of the mixture divided by the specific gravity of the dealcoholised liquid restored to its original bulk, gives the specific gravity of the dilute alcohol, and hence the percentage of the alcohol driven off; or expressed in formula—

$$\text{Sa} \times \text{Ss} = \text{Sm}, \text{ and}$$

$$\text{Sa} = \frac{\text{Sm}}{\text{Ss}},$$

Sa being the specific gravity of the diluted alcohol, Ss that of the sugar solution, and Sm that of the mixture.

The estimation of the alcohol in a wine is conducted as follows:—Take a measured quantity—say 100 cc., boil it down to about one-fourth, and add sufficient water to the dealcoholised liquid to make it up to its original bulk. Take its specific gravity at 15·5° C. Divide the specific gravity of the entire wine by the specific gravity of the same dealcoholised. The product is the specific gravity of the alcohol.

It is evident that a certain amount of error must be committed by the adoption of this method, inasmuch as we calculate a varying mixture of many different organic and inorganic substances, as if it were cane sugar only, notwithstanding that this substance is not present at all in wine. This method has been recommended by Balling and Mulder, and requires less time and experience than any other. Subsequent researches by Dr. Kraft ('Zeitschrift für anal. Chemie'—R. Fresenius), however, have shown that the time is gained at the expense of the accuracy of the determination.

Estimation of Total Free Acids.

The principal free acids in wine are tartaric, malic, and acetic acids. We shall speak afterwards of the estimation of tartaric and malic acids; at present we have only to describe the estimation of the total acidity. This is most easily accomplished by means of a standard soda solution, of such strength that 1,000 cc. of it neutralise half an equivalent of a bibasic, and a whole equivalent of a monobasic acid. Such a solution would neutralise 60 grammes of acetic acid, and 75 of tartaric acid. Measure 100 cc. of wine into a beaker, and add from a graduated burette the soda solution until the reaction of the wine is perfectly neutral, that is, when neither blue litmus nor turmeric paper is changed. The number of cc. of soda solution used, multiplied by 0·075, gives the total free acid calculated as tartaric acid in percentages. This estimation is most conveniently combined with the determination of the alcohol, just described, since also in this estimation the wine must be rendered neutral, or even alkaline.

Estimation of Volatile Acids.

Of volatile acids, only acetic acid is present in estimable quantity. Formic and propionic acids are contained in wine, but not in such quantities as could be estimated by operating upon a small quantity of wine. The estimation of acetic acid is an indirect one. 100 cc. of the wine are boiled down in a beaker to about one-fourth, and the remaining acid estimated as just described above. The difference of acidity before and after boiling is due to acetic acid, volatilised by the heat employed, while the amount of soda solution used after boiling is calculated into tartaric acid as described above; 1,000 cc. of soda solution are equal to 60 grammes of acetic acid. It is commonly recommended to distil the wine from a retort, and to estimate the acetic acid in the distillate. The objection to this method is that acetic acid would partly be volatilised as acetic ether, a neutral substance, and the result would thus become too low. We prefer, therefore, to avoid this objection and to dispense with distillation.

Estimation of Bitartrate of Potash.

Bitartrate of potash is only with difficulty soluble in water, and nearly insoluble in absolute alcohol, and still more so in a mixture of alcohol and ether. Upon this fact the methods for estimating bitartrate of potash in wine are based. Berthelot's method is commonly employed. Mix 20 cc. of wine with 100 cc. of a mixture of alcohol and ether, and let the liquid stand in a stoppered flask for two or three days. During this time nearly all the cream of tartar will have crystallised out, and may be collected upon a weighed filter, dried and weighed.

Estimation of Total Tartaric Acid.

Neutralise in 200 cc. of wine about one-fifth of the total acid with caustic potash, add 100 cc. of a mixture of alcohol and ether, and allow to crystallise for 48 hours; all tartaric acid will have separated in the form of bitartrate of potash. The difference between this estimation and that of the bitartrate of potash, existing naturally in the wine, gives the amount of free tartaric acid, as acid tartrate of potash. The total amount of acid is either ascertained from the weighed quantity of bitartrate obtained; or the potash salt may be dissolved upon the filter with boiling water, after having been washed with the mixture of alcohol and ether. The acidity of the solution is to be determined by the standard soda solution. This gives the amount of the half-combined tartaric acid, and this again doubled furnishes the total tartaric acid. A correction should be made for the solubility of the bitartrate of potash in the solution employed, namely, 0·02 per cent. of bitartrate in the wine. The above method gives results in most cases of sufficient accuracy for practical purposes, except where the amount of tartaric acid falls below 0·05 per cent. In this case neither the acidity of the precipitate, nor of the alcoholic mixture, nor of the wine itself, can be estimated within less than 0·1 cc. of standard soda solution. Another important source of error in the case of sherries and other plastered wines, is the presence of sulphate and chloride of potash in the wine, both of which are decomposed by tartaric acid on the addition of alcohol-ether; the tartaric acid combines with the potash, the sulphuric acid being set free. A higher amount of bitartrate of potash than is naturally present in the wine is obtained in such cases.

Estimation of Malic Acid.

A measured quantity of the wine (from 50 to 100 cc.) is rendered alkaline by means of lime-water, which precipitates the phosphoric and tartaric acids as lime salts. The liquid is to be filtered, and to the concentrated filtrate strong alcohol added, whereby the malic acid is precipitated as malate of lime, together with some sulphate of lime. The precipitate is collected upon a weighed filter, dried at 120° C. and weighed. The sulphuric acid may now be estimated in it by dissolving in strong hydrochloric acid, and precipitating with chloride of barium, as has been more than once described. But it will be more convenient and quicker, to incinerate the precipitate without weighing, and to estimate the amount of carbonate of lime formed from the malate of lime by the standard acid mentioned under 'Ash of Wine.' One part of carbonate of lime is equal to 1·72 parts of malate of lime, $C_4H_4CaO_5$, or 1·34 parts of malic acid, $C_4H_6O_5$.

Determination of Tannic Acid.

The presence of tannic acid, and some idea of the quantity contained in any wine, may be formed by the black or inky colour produced on the addition of a persalt of iron and acetate of potash; the use of the latter reagent, whereby tartrate of potash and acetic acid are formed, is rendered necessary because the black colour is not readily yielded in the presence of free tartaric or malic acids, but a little free acetic acid does not interfere with the reaction. Wines containing as little as 0·005 per cent. of tannic acid furnish a very marked result, and it would be quite easy to frame a quantitative iron colour test which would furnish results of considerable accuracy.

Another colour test, nearly equal in delicacy to the preceding, is furnished by a strongly ammoniacal solution of ferricyanide of potassium. If a few drops of such a solution be added to a solution of tannic acid, or to a wine containing that acid, a deep blood-red coloration takes place, the depth of which is proportionate to the amount of tannin present. The red coloration is also produced by this test, which is more applicable to white than red wines, in solutions of gallic acid, which, however, does not usually occur in wine.

Another process is the well-known gelatin process. A standard solution of gelatin, or gelatin and alum, is prepared; the amount of tannin being deduced from the quantity of the solution used, or, when gelatin alone is employed, from the weight of the dried precipitate. It is unfortunate, however, that a less quantity of gelatin than 0·06 per cent. is not determinable in this manner. There are few white wines with which solution of gelatin does not give rise to a slight cloudiness, but in red wines an abundant precipitate is produced, consisting in part of colouring matter. One of the great difficulties of using the gelatin test volumetrically is to determine the point of saturation; in this particular either the iron or ferricyanide of potassium may be applied, so as to afford help. Another difficulty consists in the impossibility of separating from the wine the compound of tannin and gelatin formed; this may be in part overcome by the use of special filtering arrangements, as by the apparatus suggested by Mr. Estcourt (see 'Chemical News,' No. 745). One hundred parts of gelatin give, with gallotannic acid, 134 to 135·6 of the compound.

Fauré found the following quantities of tannin in certain wines by means of a standard gelatin solution:—

Gelatin Solution required by 100 Parts of Wine.

Castillon	6·0 cc.	1 cc. = 0·010 gramme of tannin.
Fronsac	4·8 cc.	
Sauterne	4·0 cc.	
Barsac	4·5 cc.	
Carbonnieux	6·0 cc.	
Château Lafitte	10·1 cc.	
„ Margaux	9·3 cc.	
Latour	13·3 cc.	
Giscours	12·3 cc.	
St. Estèphe	7·0 cc.	

In a solution of gelatin and water, as little as 0·04 hundredths per cent. may be determined quantitatively; but in wine, as we have stated, not less than 0·06. This arises from the fact that the gelatin precipitate is, to some extent, soluble in the wine.

Detection of Racemic Acid.

Racemic or paratartaric acid is obtained usually from crude tartar. The mother-liquor is treated with chalk, the insoluble tartrate and racemate of lime are thrown down and separated. These are next treated with sulphuric acid, whereby the tartaric and racemic acids are liberated; the latter, when exposed to the air, crystallises, the crystals of the former being distinguished by their transparency, and those of the latter by their efflorescence.

Racemic acid is less soluble in water and alcohol than tartaric acid; one part of acid requires 5·7 parts of water at 15° C. and 4·8 of alcohol. It gives a precipitate with sulphate of lime, which tartaric acid does not; then, again, tartrate of lime is soluble in acetic acid, but the racemate of the same base is insoluble. It crystallises in double oblique rhombic prisms without hemihedric faces. Racemic acid has no action on polarised light.

Detection of Succinic Acid.

Half a litre of wine is shaken up with 40 grammes of animal charcoal, and after decolorisation the charcoal is to be well washed with cold water. The filtrate and washings are to be evaporated on a water-bath, nearly to dryness, the drying being finished under the air-pump. The residue is then to be treated repeatedly with one part of alcohol of from 90 to 92 per cent. strength, and two and a half parts of ether. The solution is evaporated, the residue exactly neutralised with lime-water, and again evaporated to dryness on a water-bath; the glycerin is then extracted with a mixture of ether and alcohol. The residuum is chiefly succinate of calcium, which may be obtained in nearly a pure state by extraction with alcohol containing 89 per cent. of spirit.

Succinic acid is soluble in 5 parts of water at 16° C. and in 2·2 of boiling water: it is rather less soluble in alcohol, slightly soluble in ether; sublimates at 140°, melts at 180°, and boils at 235° C.; it may be heated with nitric, hydrochloric, and sulphuric acids, and aqueous solution of chromic acid without decomposition. The salts of the alkalies are soluble, those of the alkaline earths are insoluble, or with difficulty soluble in water. A solution of a neutral succinate of an alkali gives with a neutral solution of a ferric salt a gelatinous red-brown precipitate of basic succinate of iron. It crystallises in rhombic or six-sided plates or prisms.

Detection of Formic Acid.

Distil the wine; neutralise the distillate with ammonia, evaporate to dryness, dissolve the residue in water, add a drop of nitrate of silver, and boil. If formic acid be present, a thickish brown precipitate of metallic silver will be produced. Should the quantity of formic acid present be very small, the greater part of the acetic acid must be removed by fractional distillation.

Estimation of Ethers in Wine.

Wine contains two classes of ethers—volatile and fixed. The ethers are organic salts, and are decomposed by solution of caustic potash into alcohol and a salt of potash, acetate, propionate, or tartrate, as the case may be.

The *volatile* ethers are first separated from the fixed by distillation. 250 cc. are to be taken and about 200 cc. distilled over. The free acid in the distillate is then *exactly* neutralised by means of soda solution and a measured quantity of standard soda solution added to the liquid, which is introduced into a flask, and is then closed with a well-fitting cork and heated for one or two hours. The ethers are decomposed, and some of the caustic soda neutralised by the acids of the ethers.

The remaining caustic soda is estimated by means of standard sulphuric acid solution, and the amount of soda which was first neutralised is calculated for acetic ether, which is the chief of the volatile ethers.

The *fixed* ethers are estimated by a similar process, but the presence of the organic nitrogenous matters makes the estimation more difficult, since the action of the caustic soda upon these substances produces large quantities of free ammonia. 500 cc. of the wine are evaporated to a small bulk, rendered alkaline with soda solution, heated in a stoppered flask, and finally distilled. The distillate contains much free ammonia and a small quantity of alcohol formed from the organic ethers. Sulphuric acid is added to the distillate to neutralise the ammonia, and the liquid distilled again. Pure dilute alcohol passes over, the strength of which is to be estimated as described under 'Alcohol.' Of course only an extremely diluted alcohol is obtained, since the amount of fixed ethers is very small. The amount of alcohol obtained is calculated for tartaric ether, the chief constituent of the fixed ethers. Thudichum and Dupré convert the alcohol obtained into acetic acid by oxidising agents, and estimate the acetic acid, which can be done alkalimetrically with much greater accuracy than the estimation of the alcohol contained in an extremely diluted spirit.

Berthelot's formula.—According to Berthelot, the quantity of ethers found in any matured wine stands always in a certain fixed relation to the amounts of alcohol and acid present, and he gives the following formula for the estimation of the ethers.

The alcohol and the acidity are to be first determined, the latter being calculated as acetic acid. A, the amount by weight of alcohol found; B, the proportion of alcohol per thousand, which corresponds to the total free acid found, 46 parts of alcohol representing 60 parts of acetic acid. By multiplying A by 1·17 and adding 2·8, we obtain a figure representing the proportion per cent. of the alcohol deduced from the acid found, which is present in the wine as ether and which we will call C. Then B, multiplied by C and divided by 100, gives the quantity of alcohol present as ethers in 1,000 parts of wine.

Suppose a sherry to contain 18 per cent. of alcohol by weight and 0·4 per cent. of acid calculated as acetic acid, then

$$C=18\times 1{\cdot}17+2{\cdot}8=23{\cdot}86$$

0·4 per cent. of acetic acid corresponds to 2·9 per thousand of alcohol, and $23{\cdot}86\times 2{\cdot}9$ and divided by $100=00{\cdot}69$ per thousand parts of wine.

The Determination of the Albuminous Matter.

If to well-fermented white wines a little chlorine water be added, the wine will remain clear; if this addition be made to new white wines and most red wines, a flocculent precipitate will appear, consisting of a compound of chlorine and albumen, and which may be collected on a filter, dried, and weighed.

In those wines, however, in which no precipitate appears on the addition of chlorine water, it is not to be inferred that albumen is absent, for in such cases a certain amount of that substance will be detected, either by combustion or by the process of Wanklyn and Chapman, devised for the determination of the albuminoid ammonia present in potable water. This process has been described in detail in the article on 'Water,' but we will here give a very brief outline of it as applied to wine.

Ten cubic centimetres of wine and 2 grammes of carbonate of soda are added to about 1,000 cc. of pure distilled water, entirely free, as previously ascertained, from ammonia; about one-third of the mixture is distilled off, and the ammonia estimated in the distillate by Nessler's test. This proceeding gives the free ammonia in the wine.

To the remaining contents of the flask are now added 2 grammes of pure permanganate of potassium, and 10 grammes of hydrate of potash previously dissolved in boiled water, to make sure of the absence of any free ammonia. Distillation is then recommenced. This treatment occasions the decomposition of the albumen and the formation of ammonia.

About one-half or two-thirds of the mixture are distilled over, and the ammonia estimated either by Nessler's test or by titration with a standard solution of sulphuric acid. The amount of ammonia multiplied by 10, Wanklyn and Chapman's formula, gives the quantity of albuminoid substance in 10 cc. of wine, or multiplied by 100, the percentage of albuminous matter in the wine.

The amount of nitrogen met with by Mulder, in certain wines, was as follows:—

Name.	Nitrogen.
Benicarlo	0·020 per cent.
Roussillon	0·029 "
St. George	0·020 "
Narbonne	0·021 "
White Côtes	0·023 "
Old Burgundy Pommard	0·040 "

The above quantities of nitrogen are made up of the nitrogen of the ammonia of the wine, of that of the ferment, and lastly of the albumen proper. That from the ammonia may, as we have seen, be separately estimated, and its amount deducted.

Thudichum and Dupré found the following quantities of albuminous matter in the wines specified below, as estimated by Wanklyn and Chapman's process:—

Ingelheimer (red)	0·373 per cent.
Port, 1851.	0·0888 "
Sherry, thirty years in bottle	0·1807 "
Madeira	0·1581 "
Niersteiner	0·355 "
Natural port	0·0527 "
Port, 1865	0·1760 "

Lastly, in twenty-five wines, chiefly sherries recently analyzed by the author, he found by the combustion process the following quantities of nitrogen :—

	Per cent.		Per cent.
Old brown sherry	0·030	Public-house sherry	0·029
Santiago	0·024	" "	0·027
Finest Montilla	0·025	" "	0·020
Amontillado	0·020	" "	0·028
Manzanilla	0·028	Hambro' sherries	0·018
Marsala	0·039	" "	0·022
Madeira	0·022	" "	0·010
"	0·018	" "	0·017
Cadiz sherry	0·025	" "	0·017
Sherry	0·022	" "	0·015
"	0·023	" "	0·014
"	0·027	" "	0·016
Restaurant sherry	0·017		

We have dwelt thus fully on the presence and determination of albuminous matter in wine, because of the practical importance attached to the enquiry, as the amount present sometimes enables us to declare, as in the case of Hambro' sherry, whether a wine is adulterated or not.

Again, excess of albumen in wine frequently causes it to spoil, helps the conversion of alcohol into acetic acid, and conduces to the generation of the fungus which forms mould in wine.

Determination of Ammonia.

A given quantity of the wine, say 100 cc., is taken, and twice the quantity of water added; one-third of this is distilled off, the residue in the retort is made slightly alkaline with carbonate of soda; and another third is distilled off into a second receiver. The object of the first distillation is the removal of the greater part of the alcohol and volatile acid. The ammonia is estimated in the second distillate either by titration with sulphuric acid or by Nessler's process. It is necessary to be watchful to ascertain that the wine does not become acid during the distillation.

Determination of the Colouring Matter of Red Wine.

Mulder's process for isolating the colouring matter of red wine is as follows :—

Acetate of lead is added to the wine so long as any precipitate is thrown down; this is collected on a filter and washed until the water ceases to be acid: the filtrate is of a pale violet colour, but becomes colourless as soon as the acid reaction disappears. The precipitate, suspended in water, is now subjected to the action of sulphuretted hydrogen; this removes all but a trace of the lead; it is again collected and washed, the filtrate being of a red colour so long as it retains its acid reaction.

The bluish-black mass thus obtained, a mixture of sulphide of lead and colouring matter, is now boiled with water to remove extractive matters—tartaric acid, sugar, gum, &c., and is then exhausted with a mixture of alcohol and acetic acid, the tincture being of a beautiful red colour; this tincture is then evaporated; it is at first red, but as evaporation proceeds, violet, and lastly, when but little acetic acid remains, of a singularly beautiful blue. The liquid is now evaporated to dryness, the fat extracted with ether, and the last trace of lead with acetic acid; what then remains consists of the colouring matter in a perfectly pure state.

Estimation of the Mineral Matter.

Evaporate in a platinum dish a measured quantity of wine—50 cc. are commonly sufficient. The residue is then to be incinerated and the ash weighed. The incineration is often a very slow and tedious process, since the organic matters burn only with very great difficulty, and the temperature must not be too high, in order to avoid loss by the volatilisation of the salts of potash. The salts of tartaric and malic acids are converted by the incineration into carbonates, which give a very good measure of the quantity of those salts. A standard sulphuric acid solution, which contains in 1,000 cc. one-half equivalent of anhydrous sulphuric acid (40 grms.), is now dropped upon the moistened ash, till the reaction is exactly neutral. The results are most conveniently calculated for caustic potash or tartrate of potash, notwithstanding that a good quantity of carbonate of lime is present in the ash, but this is derived from tartrate or malate of lime. If necessary, the soluble carbonates may be separated from the lime and magnesia salts by means of boiling water, and both separately estimated.

Estimation of Phosphoric Acid.

The phosphoric acid may either be directly precipitated from the wine by the method we are just going to describe, or better, the wine is first evaporated, incinerated, and the ash boiled with nitric acid to dissolve the phosphates. In either case, the bulk of the liquid should be as small as possible, not amounting to more than 20 cc.; 100 to 200 cc. of wine should be employed. Add to the evaporated wine, or to the solution of the ash, a solution of molybdate of ammonia in nitric acid in excess, and keep the mixture for some hours at a temperature not exceeding 50° C. All phosphoric acid is precipitated as yellow crystalline phospho-molybdate of ammonia, mixed with variable quantities of molybdanic acid. The precipitate cannot therefore be directly weighed. It is washed with some molybdate of ammonia, dissolved in dilute ammonia; and the alkaline solution, which contains now all the phosphoric acid present in the wine, precipitated with a solution of chloride of magnesium. The precipitate consists of phosphate of ammonia and magnesia. It is filtered after some hours' standing in the cold, washed with dilute ammonia, incinerated and weighed. One hundred parts of it contain 63·96 parts of phosphoric acid. For further details of the method, which requires great care, a work on analytical chemistry, as Fresenius's 'Quantitative Analysis,' may be consulted.

Estimation of Sulphuric Acid.

From 50 to 100 cc. of wine are rendered acid by pure hydrochloric acid, heated to boiling, and chloride of barium added to the boiling liquid. Immediately a white precipitate of sulphate of barium is formed, which settles very easily after some minutes' boiling. If the chloride of barium be added to the cold liquid, the sulphate of barium falls down as a very fine powder, which always passes through the pores of the filter-paper. It is separated by filtration, well washed with hot water, incinerated, and weighed; 100 parts of it contain 34·335 parts of anhydrous sulphuric acid (SO_3), or 42·49 parts of H_2SO_4.

Estimation of Chlorine.

Take 100 cc. of the wine, render them acid with pure nitric acid, and add nitrate of silver solution. Chloride of silver is precipitated, especially after agitation of the liquid. It is to be separated by filtration, dried, incinerated, and weighed in a porcelain crucible. The precipitate should be separated from the filter-paper as cleanly as possible, since the organic matter of the paper reduces the chloride to metallic silver; 100 parts of the precipitate contain 24·724 parts of chlorine.

Determination of the Total Solids.

It might be supposed that the determination of the total solid matters contained in a wine was a very simple and easy operation, and one which might be made to yield accurate results. It will be seen that any such conclusion would be erroneous.

Two methods are usually employed—one, which may be termed the direct method, consists in the evaporation of a given quantity of wine, say 10 cc., on a water-bath, drying it till it ceases to lose weight, and weighing. Now, the fault of this method is that, however carefully the evaporation may be conducted, the sugar, dextrin, and certain of the extractive matters become more or less changed, chemically and physically, from the heat to which they are subjected.

Still, this process, though not exact, furnishes valuable comparative results. Messrs. Thudichum and Dupré state that by this method they have found in a number of analyses of wine rich in sugar more sugar than the total amount of solids found; but this is in part explained by the fact that they dried the residue at a temperature of 110° C.

The second, or indirect method, is one which is also very easily performed, and which, on the whole, yields results of a more satisfactory character than the first process.

A given quantity of the wine is first freed by evaporation, or, better still, by distillation, from its alcohol; the remaining liquid containing the solids is now made up with water to its original bulk, and its specific gravity taken. The gravity thus found will correspond with the amount of solids specified in the following table of Balling:—

Sugar Table (*Temperature*, 17·5° C.)

Specific gravity.	Per-centage.	Specific gravity.	Per-centage.	Specific gravity.	Per-centage.	Specific gravity.	Per-centage.
1·0040	1·004	1·0080	2·016	1·0120	3·036	1·0160	4·064
1	·029	1	·041	1	·062	1	·090
2	·054	2	·067	2	·087	2	·116
3	·080	3	·092	3	·113	3	·141
4	·105	4	·118	4	·138	4	·167
5	·130	5	·143	5	·164	5	·193
6	·155	6	·168	6	·190	6	·219
7	·180	7	·194	7	·215	7	·245
8	·206	8	·219	8	·241	8	·270
9	·231	9	·245	9	·266	9	·296
1·0050	1·256	1·0090	2·270	1·0130	3·292	1·0170	4·322
1	·281	1	·295	1	·318	1	·347
2	·307	2	·321	2	·343	2	·374
3	·332	3	·346	3	·369	3	·400
4	·358	4	·372	4	·395	4	·426
5	·383	5	·397	5	·420	5	·451
6	·408	6	·423	6	·446	6	·477
7	·434	7	·448	7	·472	7	·503
8	·459	8	·474	8	·498	8	·529
9	·485	9	·499	9	·523	9	·555
1·0060	1·509	1·0100	2·525	1·0140	3·549	1·0180	4·581
1	·534	1	·550	1	·575	1	·607
2	·560	2	·576	2	·600	2	·633
3	·585	3	·601	3	·626	3	·659
4	·610	4	·627	4	·652	4	·685
5	·635	5	·652	5	·677	5	·710
6	·661	6	·678	6	·703	6	·736
7	·686	7	·703	7	·729	7	·762
8	·711	8	·729	8	·755	8	·788
9	·737	9	·754	9	·780	9	·814
1·0070	1·762	1·0110	2·780	1·0150	3·806	1·0190	4·840
1	·787	1	·805	1	·832	1	·866
2	·813	2	·831	2	·858	2	·892
3	·838	3	·856	3	·883	3	·918
4	·864	4	·882	4	·909	4	·944
5	·889	5	·908	5	·935	5	·970
6	·914	6	·934	6	·961	6	·996
7	·940	7	·959	7	987	7	5·022
8	·965	8	·985	8	4·012	8	·048
9	·991	9	3·010	9	·038	9	5·074

Sugar Table (Temperature, 17·5° C.)

Specific Gravity.	Percentage.	Specific Gravity.	Percentage.	Specific Gravity.	Percentage.	Specific Gravity.	Percentage.
1·0200	5·100	1·0213	·438	1·0226	·778	1·0239	·118
1	·126	4	·464	7	·804	1·0240	6·144
2	·152	5	·490	8	·830	1	·170
3	·178	6	·517	9	·856	2	·196
4	·204	7	·543	1·0230	5·882	3	·223
5	·230	8	·569	1	·908	4	·249
6	·256	9	·595	2	·934	5	·275
7	·282	1·0220	5·621	3	·961	6	·301
8	·308	1	·647	4	·987	7	·327
9	·334	2	·673	5	6·013	8	·354
1·0210	5·360	3	·699	6	·039	9	·380
1	·386	4	·725	7	·065	1·0250	6·406
2	·412	5	·751	8	·092		

This table is based upon the gravity of beer worts, but it is found to answer well for wine, an allowance or deduction being made for the greater weight of the ash in the latter; in fact, the whole of the ash found should be deducted, since the amount of the extract, minus the ash, is required. In weak thin wines, containing but little ash, the deduction is not usually of much importance, but as, in some wines, the ash amounts to as much as half a per cent., the error would be considerable if the deduction were not made.

The following total residues, minus ash, obtained by the two methods, are from Thudichum and Dupré's treatise:—

	1st method.	2nd method.	Sugar per cent.
Marsala	4·132	5·780	4·70
Port	4·632	6·909	5·26
Lachryma Christi . . .	24·262	32·022	26·784

THE ADULTERATIONS OF WINE.

Wine, as might be supposed, and as is well known, is very liable to adulteration, and this in a great variety of ways.

The practice begins with the very must itself, and may be said not to end in many cases until the wine reaches the consumer.

The composition and quality of the must vary of course with many circumstances—the kind of grape, the season, and especially with the degree of ripeness of the fruit. Some musts, as those derived from well-ripened grapes, are often particularly rich in sugar. Others again, from unripe grapes, yield a must in which acids predominate.

Dilution and Sweetening of the Must.

Now it has occurred to certain ingenious gentlemen to subject both the rich and the sour musts to special treatment. Thus M. Petiot recommends an addition of water to must which abounds in sugar, and he has elaborated his method into a system, which has even been named after him, and the wine thus manipulated is distinguished by the appellation of 'Petiotised' wine. On the other hand, M. Gall recommends an addition of sugar to poor musts; to the sour musts he adds water to reduce the acidity, and then sugar to make up for the deficiency occasioned by the addition of the water. This method too has served to immortalise the author, and such wine is known in Germany as 'Gallisirter' wine.

High are the eulogiums passed upon the wines produced from must so treated, and some enthusiastic writers would lead us to believe that they are far superior to the wines the produce solely of the juice of grapes.

Thus Petiot obtained by repeated pressure and dilution from a quantity of black grapes, which should have yielded only 60 hectolitres of wine, by the aid of 240 litres of sugar solution containing 18 per cent., 90 hectolitres of white, and 195 hectolitres of red wine—in all 300 hectolitres of what Petiot denominates 'wine in the full sense of the word.'

The Petiotised wine, according to Thudichum and Dupré, 'is less acid and more drinkable. It has more bouquet than the wine which has been made from the grapes directly. It has an extraordinary power of lasting.'

'The infusion wines resemble natural wines in all essential qualities. They contain all the essential ingredients and almost in the same proportions as the natural product. The non-essential ingredients, or those which are frequently hurtful to the natural wine, are diminished in the infused wines to such an extent that their absence is a favourable circumstance.'—*Thudichum and Dupré.*

Of course the amount of tartrate of potash and of free acid is less than in wines made from undiluted must, and hence in this respect it is urged in favour of these artificial wines, that they are more like old wines, being milder to the taste from having deposited part of their tartar. But they also contain less mineral matter generally, less potash and phosphoric acid, as well as a smaller quantity of the peculiar acids of the wine, malic and tartaric acids.

It is well established that fermentation ceases in a liquid which contains 16 per cent. of alcohol by weight, corresponding to about 32 per cent. of sugar. Now, in parts of Spain, Italy, Greece, and Madeira, the must frequently contains an amount of sugar equal to 24 per cent. of alcohol, and, since fermentation ceases above 16 per cent., of course much of the sugar in such rich musts will remain unconverted if the sugar be not brought down by dilution with water. and this fact furnishes one argument in favour of the adoption in some cases of Petiot's method; but then it may be said that grapes which furnish such a saccharine juice are scarcely fitted for wine-making at all, and that they correspond rather to raisins than to grapes of which wines are usually made—at all events, if wines be made from such grapes, they should be of the sweet class, such as Lunel and some of the sweet Sauternes.

Musts which contain only an amount of sugar equivalent to 6 or 8 per cent. of alcohol, are hardly rich enough for making wine, but it must be remembered that grapes contain different quantities of sugar according to their degree of ripeness, and hence it is a common practice to test the juice from time to time, with a view to ascertain the amount of sugar contained in it, and so to regulate the period of the ingathering. In some temperate countries—as the Rheingau—the grapes never become too ripe, and are therefore allowed to hang on the vines until the autumn is far advanced.

Regulation of the Acidity of the Must.

An important part of the process of Gall consists in the regulation of the amount of acid in the must. In bad years the grapes are so rich in acidity that the wines produced from them are too sour to be agreeable to the palate. Five parts of acid in one thousand of wine are contained in wines of good quality; in sour ones often as much as from 15 to 18 per thousand.

Now it is in such cases that the process of Gall comes into operation; but it is held by many that such sour must is not fit for the manufacture of wine. Still we would say of this process, as well as of that of Petiot, that, provided the wines so made are properly distinguished, as by the names of the authors of the process, there are cases in which the wine grower is justified in having recourse to them. Gall depresses the acidity of all must to 0·5 per cent., and raises the amount of sugar to 20 per cent. Of course, therefore, the quantity of wine so produced is greatest the sourer the original must; this to us appears to be a radical fault of the method. 'But what struck the observer as most remarkable was this circumstance, that the wine was always better than the wine from the same sour must made by the ordinary means.'—*Thudichum and Dupré.*

In the case of over-acid wines, the excess of acidity is in some cases got rid of by the direct addition of an alkali, such as carbonate of lime or soda, and in other cases by the addition of neutral tartrate of potash, as recommended by Liebig. This salt combines with a part of the free tartaric acid, forming acid tartrate of potash, which, on account of its comparative insolubility, separates.

'The addition of the carbonated alkalies or of chalk alters the bouquet of the wine.'—*Parkes.*

The Colouring of Wine.

This consists of two different processes, the one applicable to certain so-called white wines, as sherry, Madeira, and wines of a similar class; the other to red wines, especially port.

The coloration of sherry and other analogous wines is effected sometimes by the direct addition of sugar, often cane sugar, more or less caramelised, but frequently by the addition of the concentrated must, obtained by evaporation in large pans. Part of the sugar of the must is decomposed by the heat, particularly at the margin of the pan, colouring the sugar more or less deep brown. The syrup thus obtained is added to wine until the required shade of colour is obtained. Much more frequent, however, than this process is the direct addition of caramel.

The colouring of red wines is practised on an extensive scale. There are, in fact, several kinds of wine, especially port, which are as a rule artificially coloured. Frequently red wines are manufactured by dyeing white wines with some vegetable pigment. Many different plants producing red fruits are extensively cultivated solely for the purpose of extracting their colouring matters, which serve as adulterants of red wines. Black cherries, bilberries, but particularly elderberries, serve alike for this purpose, while Brazilwood or logwood is largely employed. Let no one think that this adulteration is carried on secretly; the elder-tree, for instance, is cultivated in Spain and Portugal on a large scale, and immense quantities of dried elderberries are exported from the latter country. Spain alone imported, in 1866, 145,000 kilos, while large quantities were sent to Brazil and France.

An article is extensively used for the coloration of red wines, termed *Jeropiga*. This consists usually of must, often more or less evaporated, and sometimes partly fermented, brandy, and foreign red colouring matter, for the most part that of elderberries; but another form of Jeropiga is made, which is composed of the same ingredients, minus the red dye, and this is added to wines requiring to be sweetened and fortified.

In the case of red wines the colouring matters are usually added to the grapes during crushing.

The Plastering of Wine.

The second operation to which the must or juice of the grape is frequently subjected is that known as 'Plastering.' It consists in dusting over the must a considerable quantity of burnt gypsum, plaster of Paris, or sulphate of lime. Sometimes the sulphate of lime is mixed with a proportion of chalk or carbonate of lime, or chalk is entirely substituted for the plaster. Parkes states that the substance used for plastering consists of a mixture of 80 per cent. of sulphate of lime, 12 of carbonate of lime, and 8 of quicklime, sulphide and chloride of calcium, of which from 1½ to 7 lbs. is used to one hectolitre of wine.

The practice is a very ancient one, and it prevails in Spain, Portugal, and the south of France—including especially Perpignan and Languedoc—Greece, and probably other countries; and the wines more particularly subjected to this process are sherry, port, and certain French and Greek wines.

The effect of the addition of the sulphate of lime has already been explained, and it consists principally in the removal of the tartaric acid in combination with the potash, insoluble tartrate of lime being formed, and a soluble bitter and aperient salt, sulphate of potash.

When chalk is added as well as sulphate of lime, a portion of the free tartaric acid is likewise thrown down, the acidity of the wine being of course thereby reduced.

When chalk is entirely substituted for the plaster, not only is the tartrate of lime thrown down as before and part of the free acid either removed or neutralised, but there is no formation of the highly objectionable sulphate of potash, and hence it would appear that this is a preferable mode of treating the must. Indeed, this plan has been specially recommended by Mulder.

Again, it must be remembered that the addition of either sulphate or carbonate of lime occasions the conversion of the soluble phosphates into phosphate of lime, which also would be precipitated if the acidity of the wine were not considerable. The amount of malic acid in must does not appear to have been determined with any accuracy, so that the effect of plastering on that acid has not been ascertained. From the solubility of the malate of lime one would infer that it was not precipitated from the must, and yet the slight degree of alkalinity of the ash of plastered wines would appear to lead to a contrary conclusion; we must bear in mind, however, that in the ripe grapes most of the malic acid has disappeared. But we believe that good must requires no such treatment, nor is it very easy to determine what are the actual advantages of the operation of plastering so commonly and so long practised.

It has been alleged that plastering increases the strength of wine by the removal of a portion of the water, but this belief is erroneous, as also that it aids in some way or other in the clarification of the wine, but it certainly is mischievous in other ways: thus, as already explained, it removes a great part of the tartaric acid from the wine, leaving the potash behind in the form of sulphate of potash, while at the same time it does not lessen the acidity an atom. It deprives the wine, in fact, of a very valuable salt, substituting another salt of an injurious character.

Care must be taken not to fall into the error of calculating all sulphuric acid found in the wine into sulphate of potash, since the must of grapes naturally contains a small quantity of combined sulphuric acid; and, since the determination of the quantity thus present is a matter of considerable importance in connection with the plastering of the wine, we have made some analyses of grapes and grape juice with a view to determine the question.

According to Boussingault and other authorities, the sulphate of potash naturally present in wine should not exceed three grains per bottle, but subsequent enquiries have led us to the opinion that the amount of sulphate of potash present often exceeds this very considerably, and that as much as six grains, if not more, may be present in some cases. This conclusion is based upon the following facts.

Two samples of Spanish grapes yielded 0·0451 and 0·0336 per cent. of sulphuric acid, equal to 11·46 and 8·53 grains of sulphate of potash per bottle, on an average therefore 9·99 grains.

100 parts of grapes were found to consist of 18 parts of husks and stones, and 82 parts of juice. 18 parts of the husks of a third sample of grapes contained 0·0247 of sulphuric acid, while 82 parts of the juice yielded 0·0189, equal to 4·8 grains per bottle. Calculated in the above given ratio, 18 : 82, 100 parts of the husks contain therefore 0·137 per cent., and 100 parts of the juice 0·023 per cent. of sulphuric acid, equal to 5·82 grains of sulphate of potash per bottle.

Another similar experiment showed that 100 parts of must contained 0·014 parts of sulphuric acid, equal to 3·54 grains of sulphate of potash in a bottle of one-sixth of a gallon.

The juice contains, therefore, on an average, 4·68 grains of sulphate of potash per bottle, while, as we have seen, the whole grapes yield 9·99 grains per bottle.

Hence we see that, in calculating the amount of sulphate of potash in any wine due to plastering, a deduction must be made of either the one or the other of the amounts above named, according as the wine has been made either from the juice alone, or from the juice and husks. Even in the latter case, the deduction of 10 grains per bottle would be too much, since it is very certain that the whole of the combined sulphuric acid present in the husk and stones would not be removed by the pressure and maceration to which the grapes are subjected.

Then, again, supposing it be known that the *must* has been sulphured, basing the calculation on the statement of Thudichum and Dupré, that one pound of sulphuric acid is thereby added to a butt of wine, a further deduction will have to be made; although we think that, if based upon the above statement, the reduction would be by far too great, since it amounts to no less than 24·9 grains of sulphate of potash per bottle.

Of the sulphurous acid generated by the burning of the sulphur a great part is not absorbed by the wine at all, but escapes; that however which is retained is gradually oxidised and converted into sulphuric acid; this decomposing part of the tartrate of potash, sulphate of potash is formed, tartaric acid set free, and the acidity of the wine thereby increased.

Again, it must be remembered that a portion of the sulphuric acid present in any wine may, in some cases, be derived from the operation of sulphuring the *wine* and the *casks*, that is to say, of submitting them to the fumes of burning sulphur.

The following particulars in reference to the plastering and the fumigation of wine are taken from a letter by Dr. Thudichum, which appeared early in 1874 in the 'Times.'

'Each quantity of collected grapes sufficient to yield a butt of must previously to being trodden and pressed is invariably dusted over with from 30 to 40 lbs. of burnt plaster of Paris (sulphate of lime). The effect of this practice is to precipitate all tartaric and malic acid of the must and to substitute in their place sulphuric acid. The must, therefore, as it runs from the press contains no bitartrate of potash, or so-called tartar, but sulphate of potash instead. In consequence all sherry contains nearly the whole of the potash of the must as sulphate, amounting to from 1½ kilogramme (about 3 lbs.) to 7 kilogrammes (about 14 lbs.) per butt of 484 litres or 108 gallons (equal to from 36·1 to 169·2 grains per bottle of one-sixth of a gallon).

'The common varieties of must are not only plastered but also impregnated with the fumes by the combustion of about 5 ounces of sulphur per butt, which adds about a pound of sulphuric acid to that brought in by the plaster.'

We would remark, in reference to the above quotation, that the plastering does not remove all the tartaric acid, in fact none of that which is in the free state, nor is it by any means certain that the malic acid is removed. In fact, ripe grapes are nearly if not entirely free from that acid.

The following figures by Thudichum and Dupré will illustrate the effect of plastering upon the acidity of the wine and upon the alkalinity of the ash:—'The tartaric acid present in the original juice amounted to 0·916 gramme per litre; in the sample treated with 20 per cent. of plaster it had been reduced to 0·01 gramme, the amount of malic acid remaining the same. The original juice yielded 4·085 grammes of ash per litre, containing 2·415 grammes of carbonate of potassium, while the sample treated with 20 per cent. of plaster yielded 7·255 grammes ash, containing 0·005 grammes carbonate of potassium.'

Of course the quantity of plaster actually employed is much less than that mentioned above, but at the same time the experiment illustrates in a general way the effects of the addition of sulphate of lime to the must of grapes. The amount of sulphate of potash actually met with in plastered sherries by Thudichum and Dupré ranged, as we have seen, from 36·1 to 169·2 grains per bottle, while in numerous analyses which we have made the quantities have ranged from 18·0 to 54·6 grains per bottle of one-sixth of a gallon.

But we have not yet quite done with the subject of plastering. It appears that 'the Greeks and Romans put gypsum into their new wine, stirred it often round, then let it stand for some time, and when it had settled decanted the clear liquor.' Geopon. lib. vii. p. 483. The object of this treatment, it is stated, was to clarify the wine.

The Deplastering of Wine.

It is obvious from what has already been said that the plastering of wine cannot be otherwise than most injurious to its flavour and wholesomeness, since it removes the whole of the combined tartaric, and, when carbonate of lime has been employed, part of the free acid, and since for the healthful and beneficial tartrates a bitter and aperient salt is substituted.

Hence it will be apparent that any process whereby the sulphuric acid can be removed and the original tartaric acid restored, and in the form in which it previously existed, namely, as a tartrate of potash, is highly desirable and would improve greatly the flavour and quality of all wines which had been plastered and increase very considerably their money value.

Such a process we have devised, and we have obtained for it provisional protection, with the intent to take out a patent in the names of the authors, Arthur Hill Hassall and Otto Hehner.

This process consists of two parts; in the first, the amount of combined sulphuric acid present in the wine is determined either volumetrically or gravimetrically, by means of a solution of chloride of barium, and in the second, a quantity of tartrate of barium nearly equivalent to the amount of sulphuric acid present is added to the wine, this being occasionally shaken for three or four days. At the end of this time all but the normal quantity of the sulphuric acid of the wine is precipitated as sulphate of barium, while the tartaric acid is restored in exactly the same amount in which it was originally present, this uniting with the now liberated potash gives rise once more to the formation of tartrate of potash, the most characteristic saline constituent of all genuine wines.

The tartrate of potash uniting with the free tartaric acid of the wine forms bitartrate of potash or cream of tartar in nearly the quantity in which it existed in the original and unplastered must. But since now the restoration takes place in an alcoholised liquid the bitartrate is rendered less soluble than it would be in the must, and hence a considerable separation of crystallised cream of tartar takes place very shortly after the deplastering of the wine, thus rendering it mellow, and producing at once the effect otherwise only obtainable in genuine wines by prolonged keeping.

In the process thus briefly sketched out, not a trace of barium can possibly remain in solution in the wine; first, because rather less of the baryta salt is used than is necessary to decompose the whole of the sulphates present; and second, since the sulphate of barium formed is the most insoluble of all known chemical compounds, and hence the process is free from the smallest risk.

It has been more than once stated that sulphate of potash is present in many wines to the extent of nearly one ounce per gallon. Now, bearing in mind that it is a nauseous, bitter and aperient salt, it is not possible but that the wines should be improved by its removal and by the restoration of its original wholesome tartaric acid; and indeed, the improvement is very obvious when the plastered and the deplastered wines are tested and tasted one against the other. In fact the improvement is so great that it unquestionably makes a difference of several shillings per dozen in the value of any wines so deplastered.

Fortification of Wine.

We have now finished with the description of the practices resorted to in the treatment of the must, and we have to describe those to which the fermented liquid or wine is subjected; and first to treat of the fortification of wine.

It is alleged that the addition of spirit to wine is rendered necessary in order to arrest fermentation and so to avoid acetification, and to make the wine keep, so as to allow of its bearing the voyage from France, Spain and Portugal or elsewhere to this country, but if all this be true, then it would follow that no wines can be imported and kept for any length of time which are not fortified. But this we know is far from being the case, as some of the finest and most costly wines contain but a moderate amount of alcohol and yet keep and indeed improve by keeping, for many years.

The practice of adding spirit to port, sherry, Madeira, and all the stronger wines is all but universal, while the same addition is constantly made to a very large proportion of what may be termed the lighter wines, both white and red, and including alike those of Germany and France.

It is a grave question for consideration whether this practice ought to be allowed in the case of wine to be regarded as genuine; and, if allowed, certain limits beyond which it ought not to be carried should be specified, these probably varying to some extent with the kind of wine operated upon. Supposing it to be conceded that the addition of spirit is in some cases necessary and allowable, yet such wines ought to be classed differently, so as to distinguish them from natural wines or those the direct product of the fermentation of the juice of the grape. Again, those wines which contain added grape spirit should be distinguished from those to which corn, potato, and other similar spirit has been added. In fact, in no true sense can wines which have been thus treated be considered as genuine grape wine; such mixtures must be regarded as artificial productions.

Again, most certainly the amount of spirit added should be confined within the limits of that which the grape itself is capable of affording.

We know really that the spirit added is rarely grape spirit, but is that derived from grain or the potato, while the wine is brought up to a strength far beyond that which grape juice can yield—first, because it rarely contains sufficient sugar to generate such a quantity; and second, because, if it did, fermentation would be stopped in the wine by the alcohol formed before all the sugar was converted.

The composition and consequently the specific gravity of grape juice varies much in accordance with a great variety of circumstances, as the soil, the condition of the grape as to its ripeness, and climate. That important constituent, sugar, is especially liable to variation. From data given by Mulder we find that the specific gravity of the must ranges from 1·039 to 1·1283; the mean of all the gravities being 1·076. From these gravities he deduces the following approximate results, that the sugar of must of different countries varies between 13 and 30 per cent. Now 198 parts of sugar represent and are convertible into 92 parts of alcohol by weight, so that the juice of French and German grapes should furnish from 6 to 14 per cent. of alcohol, equal to from 13·09 to 30·26 of proof spirit, but since in the manufacture of wine some of the sugar remains unconverted and some of the alcohol is evaporated, the yield of alcohol is usually less than that stated, so that the *maximum* yield may be taken at about 28 per cent., and this is really found to be somewhat beyond the quantity of alcohol furnished by the strongest of the natural wines, the sherries and ports of Spain. Thudichum and Dupré state that the must of Xerez contains from 14·6 to 24 per cent. of sugar, and that therefore it can only by fermentation yield from 14 to 23 per cent. of proof spirit, or, taking one sherry with another, a mean of 18·5 per cent. They say they are quite certain that no natural sherry ever ranges over 12 per cent. of alcohol by weight equal to 26·0 per cent. of proof spirit.

Five samples of vino fino from the San Lucar districts, and which were declared to be the product of the natural fermentation of the must, were found to contain 26·5 of proof spirit, equal to 17 degrees centigrade on Gay-Lussac's scale; 27·2, equal to 17·5 per cent. alcohol; 26·5 proof spirit, 27·9 or nearly 18 per cent. of alcohol, and 27·2 of proof spirit or 17·5 per cent. of alcohol. These quantities are somewhat above the highest amount given by Thudichum, and approach that given by Mulder, namely, 28 per cent. These higher figures may probably be explained by the circumstance that the strength of a wine in alcohol increases somewhat by keeping.

With respect to the strength of *natural* wines some valuable information has recently been obtained by the Commissioners of Customs, through Mr. Keen, one of their inspectors. Of 554 samples of wine furnished by Spain, 282 were found to be free from added spirit, and of these the average strength was ascertained to be 24·10 degrees of proof spirit. Of the 557 samples of Portuguese wines, 381 were ascertained to be natural and to furnish 24·27 per cent. of proof spirit.

With regard to *fortified wines* one was ascertained to have a strength of 56·7 degrees, a strength not much inferior to that of old Cognac brandy. It was found, however, that the average strength of the whole of the Spanish wines tested, including the 272 which had been more or less fortified, amounted to 28·10, the average strength of the Portuguese wines, including the 176 which had been fortified, amounted to only 25·96; but it must not be supposed that these figures represent the average strength of the wines sold in this country under the names of sherry and port, since natural wines are here rarely met with. As is elsewhere stated, the average of samples of sherry tested by us reached 38·3 per cent. of proof spirit.

The practice of fortification is not at an end even when the wine reaches this country, for in many cases it receives further doses of spirit in our bonded warehouses and in the cellars of some of our wine merchants. Further details will be given under the heads of several of the wines, the adulteration of which is hereafter considered.

The Flavouring of Wine.

Not unfrequently the flavour and aroma of wines are imitated by various artificial means. Thus *astringency* is imparted by means of tannin or substances containing it, as the *sawdust of oak*, or a tincture made from the *seeds of the grape*, while an artificial *bouquet* is produced, amongst other things, by means of extract of *sweet briar*, *elderflowers*, *orris root*, *cherry* and *laurel water*.

It is by means of a tincture made from the flowers of the elder-tree that the Muscatel flavour and bouquet are imparted to Moselle wine.

The Blending of Wine.

Frequently two or more kinds of wine are mixed together, sometimes with a view either to the production of a more drinkable wine than either would be in its separate state, but often in order to suit the taste of the customer. Wine consumers are usually ignorant about the principles of wine-growing, and they demand from one year to the other exactly the same quality of wine, with the same flavour, strength, and appearance, notwithstanding that the same quality of wine is rarely naturally produced. To suit this demand the wines are blended, either one kind with another or by the addition of spirit and sugar, till the required quality and strength are obtained: thus sherries, as ordinarily sold, rarely contain less than 17 or 18 per cent. of alcohol, and often more.

The wine growers themselves hardly ever mix several qualities of wine together. The agents for export buy them from the growers and blend them according to the country the wines are to go to, and the different customers. Clarets are especially so blended. 'Château Neuf du Pape is used as "doctor" to feeble, acid, and pale wines of bad years. Wine of the Ermitage goes to Bordeaux and is there mixed with the feebler Gironde wines.' (Thudichum.) These two famous classes of wine never therefore occur in a pure, unmixed state in commerce, since their value for adulterating Bordeaux wines is too great. A second kind of blending frequently practised consists, in the case of sherries, in the addition of small quantities of stock or mother wines termed 'Soleras;' see p. 792, and in the case of champagne of 'Liqueur,' which consists of wine of the best description, mixed with sugar and usually brandy. The very best wines are used to give to the first-class champagnes their fine flavour, while inferior qualities receive only an addition of brandy and sugar. The composition of these liqueurs varies according to each description of wine, weak samples requiring more spirit than strong and full-flavoured wines. The champagne to be exported to different countries receives different additions: thus for England full-flavoured wines are required, and only a small quantity of liqueur is added; for Russia much liqueur is added, diminishing thereby the acidity, and making the champagne appear sweet and flat; for Austria and parts of Germany it is manufactured very sweet, while France receives only a moderate quantity.

Factitious Wines.

These wines are manufactured on an enormous scale, certain districts and places being famous or infamous for the manufacture. One of these places is Cette, in Normandy, where those who follow this trade do not hesitate to place over their doors boards with the announcement, 'Wines Manufactured Here.' Another is Bingen on the Rhine.

By the term factitious wines two things may be meant: one, that the articles denominated wine may be entirely artificial products, not containing any wine the produce of the grape, but such compounds are rarely manufactured; the other, that the wines are made up by various additions and by blending in imitation of certain well-known descriptions of wine, as by the conversion of white wines into red, of claret into port, of certain light wines into sherry, as Hamburg or Hambro' sherry, and many other like practices.

Lead in Wine.

But wine not unfrequently contains *lead*. In some cases this is an accidental impurity or impregnation, but more frequently it is to be regarded as an adulteration.

When lead is accidentally present it is derived from the shot used in cleaning the bottles.

When added intentionally to wine, it is so for the purpose of preventing it from turning sour.

Dr. Watson[1] states that the practice of adding lead to wine was at one time common in Paris.

Dr. Warren[2] relates an instance in which thirty-two persons were made seriously ill by drinking wine adulterated with lead; one of them died, and another became paralytic.

In Dr. Ure's 'Dictionary,' we find these remarks in relation to the use of lead in France:—'This distemper (excessive acidity) formerly gave rise to the very dangerous practice of adding litharge as a sweetener, whereby a quantity of acetate or sugar of lead was formed in the liquor, productive of the most deleterious consequences to those who drank of it. In France the regulations of the police and the enlightened surveillance of the Council of Salubrity have completely put down this gross abuse.'

Lastly, Graham, in his 'Treatise on Wine Making,' published many years since, under the article 'Secrets,' belonging to the mysteries of vintners, recommends lead to be used for several purposes. The following receipts are copied from that work:—

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[1] 'Chemical Essays,' vol. viii. p. 369.

[2] 'Medical Trans.' vol. ii. p. 80.

'*To hinder Wine from turning.*

'Put a pound of lead melted in water into your cask pretty warm, and stop it close.'

'*To soften Grey Wine.*

'Put in a little vinegar wherein litharge has been well steeped, and boil some honey to draw out the wax. Strain it through a cloth, and put a quart of it into a tierce (42 gallons) of wine, and *this will mend it.*'

To cure Wine of its Muddiness.

A lump of sugar of lead of the size of a walnut and a tablespoonful of sal enixum are directed to be added to a tierce of wine.

Accum has the following remarks in reference to the use of lead in wine:—

'The most dangerous adulteration of wine is by some preparations of lead that possess the property of stopping the progress of acescence in wine, and also of rendering white wines, when muddy, transparent. I have good reason to state that lead is certainly employed for this purpose.'

'Lead, in whatever state it is taken into the stomach, occasions terrible diseases, and wine adulterated with the minutest quantity of it becomes a slow poison. The merchant or dealer who practises this dangerous sophistication adds the crime of murder to that of fraud, and deliberately scatters the seeds of disease and death amongst those consumers who contribute to his emolument. If to deface the current coin of the realm be denounced as a capital offence, what punishment should be awarded against a practice which converts into poison a liquor used for sacred purposes!' These remarks have a wider application than to the subject of the adulteration of wine with lead.

It appears that no real necessity ever exists for having recourse to lead to remedy the more usual defects of wine.

It may here be stated that the muddiness, and especially the ropiness and viscidity of wine, are due to the presence of an azotised matter precipitable by means of tannin. It is in white wines deficient in tannin that this malady chiefly occurs. M. François recommends for its cure the use of the bruised berries of the mountain ash in a somewhat unripe state, and of which one pound well stirred in is sufficient for a barrel. 'When wine becomes stringy, in which case acetic and lactic acids are formed, it may be improved by adding a little tea. About one ounce of tea boiled in two quarts of water should be added to about forty gallons of wine. Bitter wine is treated with hard water or sulphur, bad smelling wine with charcoal, too astringent wine with gelatine, wine which tastes of the cask with olive oil.'—*Parkes.*

The wines of the adulteration of which we propose to treat are chiefly *Sherry, Madeira, Cape, Port, French red wines, Champagne, German, Greek, and Australian wines.*

SHERRY AND ITS ADULTERATIONS.

The grapes from which this wine is made are white; they are grown in the province of Andalusia, near Cadiz, in Spain: those which furnish the better qualities of wine are cultivated in the vineyards surrounding the town of Xeres de la Frontera, and hence the wine is called the wine of Xeres.

The greatest care and labour are bestowed upon the cultivation of the vines from the fruit of which sherry is made.

The grapes are not gathered until they are very ripe, and even somewhat shrivelled with the heat of the sun; sometimes the fruit after being plucked is exposed to the sun for a day or two, and for the very best wine the finest grapes only are used.

The fermentation is continued until nearly all the sugar has become converted, and the wine is often not drawn off for four or five months after the commencement of fermentation. It is at first of a pale straw colour, but darkens with age. Sometimes, however, a peculiar colouring liquid, termed 'arrope,' is added. This is prepared by boiling sherry down to a syrup. It is by the addition of this substance that the dark sherries are prepared.

The sherry termed *Amontillado*, and which at the present time is so much in favour with us, is a very dry wine. A singular fact with regard to this wine is that its peculiarities are not due to any ascertained causes capable of imitation, but are entirely accidental so far as the manufacture is concerned. In attempting to prepare it the fruit is plucked at a much earlier period, and trodden by the peasants; but of a hundred butts of wine made from the same grapes and by the same process, some only will be Amontillado and some ordinary sherry.

Sherry bears too high a price and is too extensively consumed to escape the hands of adulterators.

All sherries should be divided into three classes; 1st, *genuine* and natural sherries, the produce, without the addition of any kind, of the juice of the grape; 2nd, *fortified* sherries, strengthened, sweetened, and coloured with spirit, sugar, and colouring all derived from the grape; and 3rd, *adulterated* sherries, not wines really, not sherries at all, but mixtures, fortified, sweetened, and coloured with spirit, sugar and colouring not derived from the grape. These mixtures, if sold at all under the name of sherry, must certainly be regarded as adulterated. If this view be not enforced, then it follows that all mixtures of foreign spirit, sugar, and colouring, with possibly a dash of genuine grape wine, must be accepted, drunk, and paid for by the public as sherry, and on the same footing as the really genuine products of the grape.

Now, from all we know, and all we can learn, there is scarcely a single *natural* sherry in this country, that is to say, a sherry which belongs to the first division, and which consists solely of the fermented juice of the grape without addition of any kind.

Thudichum and Dupré state that no natural sherry ever contains more than 12 per cent. of alcohol by weight, and we may safely conclude, when more than that amount is present, it has been fortified. They write now however—'Some Amontillados and sherries are offered for sale which in their alcoholicity (12 to 13·6 per cent.) closely approach the undoubtedly unbrandied and natural wines of the Rheingau and Sauternes, though containing about one or two per cent. more than these. Their taste is freely vinous, rich, pure, mellow, and quite free from heat or the taste of added spirit.'

That there should be no natural sherry in this country is certainly very extraordinary, since these wines are largely produced and consumed in the countries in which sherry is made. In explanation of this absence of genuine sherry in this country, it is said that it will not stand the voyage, and that, if it would, it is such a different article to that to which the British public has by long abuse become accustomed, that it would not be drunk. We decline to accept either of these statements; we see no reason whatever why natural sherry, with its alcohol reaching, in some cases, as high as 27, or even possibly 28 per cent. of proof spirit, should not bear the voyage and keep quite as well as the wines of France, Germany, Hungary, and Greece. Further, we see no reason for believing that well and carefully prepared natural sherry, if introduced into this country, would not be approved and consumed. No doubt the palates of the wine-drinkers of this country have been seriously vitiated and perverted, and that they have been taught to some extent to like the fiery and saccharine compounds and liquors with which they have been supplied under the name of sherry; no doubt, also, that if a quantity of sugar be added to sherry it becomes necessary to fortify it with much spirit to prevent a secondary fermentation setting in; but we hold that these strongly fortified wines are not sherries in any proper or strict sense; that their habitual consumption in an undiluted form is injurious to the stomach, impedes and deranges digestion, over-stimulates the nervous system, and, in fine, impairs the general health. The drinking of such wines is a form of dram-drinking, and is a worse habit than the drinking of spirits and water, because these wines are usually very much stronger than spirits and water as ordinarily consumed. Spirits are mostly drunk in the proportion of a wineglass of spirit made up with water to a tumblerful. Now, such a mixture will usually contain about from 16 to 20 per cent. of proof spirit, whereas most sherries sold in this country contain nearly 40 per cent.

We have said that scarcely a single natural sherry is to be met with in this country. The very finest and purest sherries imported belong to our second division, and are fortified with grape spirit only, or with grape spirit, grape sugar, and grape colouring, according to the kind; but the great bulk, we fear, of the sherries consumed in Great Britain are to be referred to the third division, and contain foreign spirit, foreign sugar and colouring, and are, in fact, mixed and adulterated articles.

But there is really a fourth class of sherries—those into which very little wine at all really enters, or, if it does, it is wine of a totally different class and name: to this class belongs Hambro' sherry; and since this name has become somewhat a term of reproach, the name of Elbe sherry has to some extent been substituted; and to this class also belongs much of the cheap sherry so extensively advertised and consumed, and so commonly vended at public-houses and restaurants.

The adulteration of sherry commences with the must or juice of the grape itself, which is almost constantly prior to fermentation dusted over as already described at length with a considerable quantity of *plaster of Paris* or *sulphate of lime*; the commoner varieties being not only plastered, but also, as already noticed, impregnated with the fumes derived from *burning sulphur*. The following particulars in reference to the manufacture and adulteration of sherry are taken from the letter of Dr. Thudichum to the 'Times,' already quoted:—

'The must ferments in the sheds called bodegas, there being no cellars properly so called at Xeres. In a fortnight the sugar has all fermented away, and the must is transformed into wine. This is allowed to deposit its lees during some months, and is racked in the following February or March. On this occasion some *brandy* is added to the wine, by which its alcoholicity rises to about 29 per cent. of proof spirit. In spring and early summer the wine (still termed "mosto," and so to the time of the next harvest) undergoes what is termed its first evolution, and after that is ready for further preparation.

'This consists in the addition of various ingredients which impart colour, sweetness, spirit, and flavour. Colour is imparted by the addition of *caramel*, produced by the boiling down in coppers of previously plastered grape juice; the brown syrup is dissolved in wine and spirit, so as to form a deep brown liquid, containing from 35 to 50 per cent. of proof spirit, termed "color," or "vino de color." Frequently caramel made from *cane sugar* is used instead of that made from grapes. Some colour is made from the juice of rotten or otherwise inferior grapes. Sweetness is imparted by the addition of "dulce"—that is, must made from grapes dried for some days in the sun, to which one-sixth of its volume of spirit, of the strength of 40° by Cartier's alcoholometer, has been added (a process by which all fermentation becomes impossible). Every hundred litres of dulce contain, therefore, 19 litres of absolute alcohol, equal to 33·78 per cent. of proof spirit. Flavour is imparted by the addition of some old selected wine, which is kept in so-called 'soleras.' Ultimately brandy is added to the mixture to the extent of fortifying it up to 35 as the *minimum*, most frequently up to 40 or 42, and sometimes, as your custom-house correspondent proved, up to 50 per cent. of proof spirit.

'In a butt of ordinary sherry (40 jars) there is mostly one-fifth of its volume of dulce (eight jars); consequently, about one-sixth of unfermented grape juice, and which remains unfermented. The better sherries are made less sweet, and only the few finest varieties are left unsweetened. The "dulce" is never plastered, and therefore its addition depresses a little the large quantity of sulphate of potash introduced by the "colour."

'Sherries contain from 1½ to 8 grammes of *sulphuric acid* as potash salt per litre (equal to from 17·5 to 93·3 grains per bottle of one-sixth gallon), and the more the older and better they are: most "soleras" are near the highest figure.'

According to Mr. Bernard a butt of sherry intended for the English market in 1860 was made up as follows:—

1 jar of spirit, about 60 o.p.
8 jars of sweet wine, or dulce.
7 jars of soleras or mother wine.
10 jars of dry wine, 1854.
14 jars of dry wine, 1859.
40 jars of sherry.

Previous to its exportation, a portion of brandy is nearly always added to sherry. The practice of brandying wine is a very objectionable one, since it cannot fail to injure the delicacy of the flavour of the wine, and to retard those natural changes in it consequent upon keeping, and which are so improving to its quality.

Low-priced sherries are imported from Spain at about 18*l.* per butt, expressly for adulteration. On their arrival they are mixed with *Cape wine* and *cheap brandy*, and the mixture is flavoured in imitation of good sherry, the colour being either increased or diminished according as brown or pale sherry is required.

'There is a place at Cadiz called the Aguada, where inferior wines are received from various parts of Spain for the purpose of mixing sherry to be shipped to England and other countries as sherry wine. The wine from the Condado de Niebla is preferred to any other wine for mixing.'—*Thudichum and Dupré.*

At the Bay of Rosas also there is a mixing station, where wines are prepared for North and South America.

The author of the 'Tricks of Trade' states that at Cette, in France, great quantities of sherry are made up and shipped for the English market, the composition of which is nothing more than a *cheap white wine*, strengthened with *brandy*, coloured with *treacle*, and flavoured with *almonds*.

Lastly, the same writer states, a kind of sherry is manufactured in this country, the basis of which is *pale malt* and *sugar candy*, a small quantity of French *brandy* and *inferior wine* being added to flavour the mixture.

The practice of restoring muddy or ropy wines by means of *lead* is also resorted to in the case of sherry and most of the other wines.

Genuine sherry is a very wholesome wine, in consequence of its freedom from acidity, sugar, and other extractive matters.

A variety of sherry, the well-known *Manzanilla*, is produced in the district of San Lucar; the grape from which it is made is said to be full of flavour and to ripen early. 'The wine is rank and common, but improves in taste and flavour by keeping. When its fermentation is perfect it is of light body, light colour, and has great lasting qualities; but withal it is so peculiar that a person unaccustomed to it would believe it to be a medicinal tincture rather than a wine, and require some length of time to habituate himself to its enjoyment.'—*Thudichum and Dupré.*

'Some derive the name from the town of Manzanilla in the Condado de Niebla, near Sevilla. Others believe it to be derived from manzana, an apple. Others again think that its taste, flavour and fragrance, and slight bitterness remind of the camomile flower; and that, as this is termed Manzanilla, the wine was called after it. It is also alleged, but by no means proved, that some descriptions of Manzanilla wine are produced by the addition to ordinary wine of *essential oil of camomile* and other ingredients.'— *Thudichum and Dupré.*

The wine which is produced in the island of Sicily known as *Marsala*, when exported to England is always brandied, and most of that which arrives there is made up in imitation of sherry. Nevertheless, very excellent Marsala is frequently met with in this country.

We will now proceed to set forth the results of the analyses of a great variety of wines of the sherry class. Before doing so, we will make a few remarks on the principal *saline* and *mineral* substances present in the *juice* of the grape and in the *wine* made therefrom.

The principal saline and mineral substances present in grape juice, as already elsewhere stated, are free *tartaric* and *malic acids*, *tartrate of potash*, *tartrate of lime*, *sulphate of potash*, *chloride of sodium*, *phosphates of lime* and *magnesia*, *manganese*, *iron*, and *silicic acid*. The malic acid occurs in largest proportion in unripe grapes.

The different proportions of the inorganic constituents of wine exert an important influence upon the quality of the wine. It is, however, much to be regretted that very few reliable analyses exist of the ash of pure must, and particularly of that from which sherry is obtained, and still fewer of the ash of pure and natural sherry; so that there are but slight data to go upon whereby the exact amount and composition of the ash either of the pure must or the pure sherry may be determined. As far as the analyses recorded go, it would appear that the ash of genuine sherry amounts to about 0·25 per cent. of the wine, equal to about 29·2 grains per bottle of one-sixth of a gallon, and the sulphuric acid to about 0·013, equal to 1·4 grain per bottle. As will appear hereafter, these data are of considerable importance in the determination of the questions of the genuineness and of the plastering of the sherries and other wines, the results of the analysis of which are about to be stated in detail.

	Old brown Sherry, 20 years in bottle.	Santiago, 1858.	Finest Montilla.	Amontillado.	Manzanilla.	Marsala.
Spec. grav. at 15·5° C.	1004·48	990·0	990·5	987·6	984·0	1003·34
Absolute alcohol by weight	16·210	14·640	15·830	17·098	20·333	15·523
Proof spirit	35·03	31·73	34·32	36·80	43·61	33·65
Grape sugar	4·015	0·087	1·553	0·991	0·780	3·598
Cane sugar	none.	none.	none.	none.	none.	none.
Tartaric acid	0·405	0·426	0·411	0·375	0·306	0·485
Acetic acid	0·049	0·067	0·042	0·021	0·050	0·054
Sulphuric acid	0·113	0·206	0·087	0·087	0·163	0·136
Phosphoric acid	0·027	0·021	0·026	0·017	0·023	0·059
Total solids	6·493	3·005	3·322	2·422	2·464	5·963
Ash	0·411	0·602	0·629	0·532	0·404	0·412
Nitrogen	0·030	0·024	0·025	0·020	0·028	0·034
Alkalinity of ash	0·028	0·044	0·019	0·019	0·028	0·026
Sulphate of potash, grains per bottle	28·7	52·2	21·9	21·9	41·3	34·6
Bitartrate of potash, grains per bottle	13·2	20·4	8·8	8·8	12·8	12·0

	Old Buhol Madeira.	Old Madeira.	Cadiz Sherry.	Sherry.	Sherry.	Pale Sherry.
Spec. grav. at 15·5° C.	1002·08	1000·65	990·1	988·9	993·2	990·2
Absolute alcohol by weight	16·084	16·155	17·584	18·923	18·923	17·903
Proof spirit	34·83	34·93	37·83	40·64	40·64	38·52
Grape sugar	2·348	3·652	1·243	1·264	2·630	1·018
Cane sugar	none.	none.	none.	none.	none.	none.
Tartaric acid	0·526	0·531	0·432	0·397	0·324	0 360
Acetic acid	0·088	0·054	0·026	0·071	0·099	0·036
Sulphuric acid	0·132	0·135	0·210	0·071	0·153	0·178
Phosphoric acid	0·084	0·067	0 010	0·018	0·019	0·012
Total solids	6·409	5·925	2·764	3·174	4·406	3·594
Ash	0·349	0·342	0·500	0·474	0·444	0·466
Nitrogen	0·022	0·018	0·025	0·022	0·023	0·027
Alkalinity of ash	0·036	0·053	0·009	0·006	0·008	0·010
Sulphate of potash, grains per bottle	33·5	34·1	53·3	18·0	39·6	45·0
Bitartrate of potash, grains per bottle	16·8	24·8	4·0	2·8	3·6	4·8

	Restaurant Sherry.	Public-house Sherry.	Public-house Sherry.	Public-house Sherry.	Public-house Sherry.	Hambro' Sherry.	Hambro' Sherry.
Spec. grav. at 15·5° C.	991·8	993·7	997·9	990·8	995·8	995·3	986·5
Absolute alcohol by weight	18·538	18·847	18·154	17·584	18·231	18·613	17·250
Proof spirit	39·83	40·47	39·03	37·84	39·19	39·99	37·13
Grape sugar	2·493	1·754	1·421	2·055	1·948	4·383	1·753
Cane sugar	none.	1·350	1·741	0·711	1·951	none.	0·481
Tartaric acid	0·360	0·445	0·360	0·330	0·368	0·285	0·219
Acetic acid	0·045	0·025	0·066	0·074	0·045	0·006	0·123
Sulphuric acid	0·096	0·216	0·135	0·192	0·183	0·034	0 007
Phosphoric acid	0·022	0·022	0·017	0·025	0·024	0·015	0·005
Total solids	3·926	4·888	5·776	4·082	5·594	4·976	2·907
Ash	0·326	0·502	0·390	0·482	0·480	0·124	0·145
Nitrogen	0·017	0·029	0·027	0·020	0·028	0·018	0·018
Alkalinity of ash	0·016	0·008	0·010	0·012	0·005	0·013	0·012
Sulphate of potash, grains per bottle	24·4	54·6	33·9	48·7	46·5	8·5	1·7
Bitartrate of potash, grains per bottle	7·6	3·6	4·8	5·6	2·4	6·0	5·6

	Sherry.	Sherry.	Sherry.	Sherry.	Xeres.	Vino fino.	Espe-rado.
Spec. grav. at 15·5° C.	984·8	986·2	994·2	997·0	1·0584	983·0	988·1
Absolute alcohol by weight	16·154	17·33	17·582	17·453	13·23	18·23	17·25
Proof spirit	34·94	37·31	37·83	37·51	28·62	39·19	37·13
Grape sugar	0·145	1·382	2·524	3·118	5·82	1·401	1·97
Cane sugar	—	—	—	—	16·35	—	—
Tartaric acid	0·307	0·360	0·372	0·373	0·153	0·331	0·390
Acetic acid	0·065	0·042	0·041	0·020		0·028	0·042
Sulphuric acid	0·230	0·216	0·198	0·189	—	0·206	0·181
Phosphoric acid	0·019	0·024	0·021	0·025	—	0·016	0·018
Total solids	1·610	2·499	4·736	4·892	23·89	2·221	2·74
Ash	0·472	0·472	0·500	0·483	0·14	0·342	0·440
Alkalinity of ash	0·040	—	—	—	—	—	—
Sulphate of potash, grains per bottle	58·23	54·7	50·1	47·9	—	52·31	45·82

	Sherry.	Hamburg Sherry.					Manzanilla.
Spec. grav. at 15·5° C.	990·9	997·3	997·4	989·5	994·7	992·4	988·4
Absolute alcohol by weight	17·307	18·231	18·361	17·094	17·563	18·230	12·384
Proof spirit	37·26	39·19	39·47	36·80	37·79	39·19	26·81
Grape sugar	—	4·527	6·147	3·838	5·106	6·200	0·184
Cane sugar	—	0·430	—	—	—	—	—
Tartaric acid	0·432	0·437	0·372	0·355	0·352	0·346	0·375
Acetic acid	0·019	0·019	0·023	0·047	0·045	0·039	0·097
Sulphuric acid	0·154	0·026	0·019	0·023	0·020	0·054	0·041
Phosphoric acid	—	0·021	0·017	0·018	0·018	0·015	0·021
Total solids	3·134	6·930	6·758	4·628	6·324	6·522	1·534
Ash	0·300	0·088	0·116	0·131	0·166	0·344	0·243
Alkalinity of ash	—	0·033	0·021	0·028	0·030	0·038	0·061
Sulphate of potash, grains per bottle	38·99	6·24	4·81	11·93	5·06	13·67	10·37

	Sherries from the Pure Wine Association.						
Spec. grav. at 15·5° C.	988·8	988·3	992·1	986·8	994·8	989·8	985·9
Absolute alcohol by weight.	12·066	12·231	14·909	16·384	14·636	14·364	15·667
Proof spirit	26·12	26·49	32·38	35·40	31·71	31·09	33·97
Grape sugar	0·242	0·308	3·265	0·801	2·273	0·585	1·683
Cane sugar	—	—	—	—	—	—	—
Tartaric acid	0·307	0·322	0·330	0·307	0·292	0·312	0·304
Acetic acid	0·066	0·048	0·107	0·048	0·130	0·057	0·038
Sulphuric acid	0·029	0·043	0·029	none.	0·044	0·027	0·044
Phosphoric acid	0·022	0·025	0·027	0·029	0·027	0·019	0·031
Total solids	1·940	1·991	3·472	2·602	3·703	2·856	2·448
Ash	0·278	0·293	0·249	0·228	0·294	0·260	0·272
Alkalinity of ash	0·089	0·094	0·083	0·090	0·086	0·087	0·099
Sulphate of potash, grains per bottle	7·34	10·85	7·34	none.	11·14	6·84	11·14

Reviewing the first thirty-two analyses above given, it appears:—

1. That thirty-one of the thirty-two samples are *fortified* with extraneous spirit to a large extent. This spirit, doubtless, in nearly all cases, and probably in every instance, is derived either from corn, beetroot, or potato, and not from the grape. While the average amount of proof spirit furnished by the must from which sherries are made at Xeres, according to the best authorities, is about 19 per cent., the lowest quantity found by the author was 28·62, and the highest 43·61, the mean of all the analyses being 37·44. In fact, the quantity of spirit added falls not very far short of that actually furnished by the fermentation of the grape juice itself.

2. That twenty-six of the thirty-two samples of wine were de-

cidedly *plastered*. The quantity of sulphate of potash found in the wines, after deducting six grains per bottle, being the full amount met with in natural sherry, ranged from 12·0 per bottle to 52·23 grains, if we exclude the artificially compounded Hambro' sherries. These quantities give 72·0 grains as the lowest, and 313·38 grains as the highest amount per gallon. It will be seen therefore that these analyses bear out the statement of Dr. Thudichum that all the sherries imported into this country are plastered—that is to say, the must is dusted over with plaster of Paris or sulphate of lime; in addition to which it is also frequently impregnated with the fumes of burning sulphur, whereby a still further quantity of sulphuric acid is introduced into the wine. Thudichum gives the quantity of sulphate of potash contained in sherries as varying from 36·1 to 169·2 grains per bottle of one-sixth of a gallon, or per gallon from 216·6 to 1015·2 grains. It will be seen that our highest quantity per bottle amounts to 58·2, and, deducting 6 grains for the full normal amount ever present, there remain 313·4 grains per gallon, or about three-quarters of an ounce; the quantity of sulphate of potash therefore met with in these analyses is much below the amount given by Dr. Thudichum, namely, rather over two and a quarter ounces.

3. That in addition to the fortifying and plastering, seven of the wines contained considerable amounts of *cane sugar*, the presence of which affords of course clear evidence of adulteration.

4. That some of the Hambro' and public-house sherries contained very little wine at all, but consisted chiefly of spirit, sugar, and water, flavoured; in fact, these mixtures could hardly be said to have any claim to be regarded as wines at all.

5. That in striking contrast with the above results, in respect to the amounts of alcohol and sulphate of potash found, are the wines of the Pure Wine Association—these being for the most part unbrandied and unplastered.

We have stated that several of the samples were of the highest quality obtainable in this country, and were tested in order to furnish the best procurable standards for comparison; and yet, excellent as many of those samples were, judged by the only standards we have to guide us in this country, it will be seen that not one of the thirty-two wines examined can be regarded as the pure and natural product of the grape alone.

MADEIRA AND ITS ADULTERATIONS.

The different qualities of Madeira are distinguished as south and north wines, according to the side of the island on which the plants were grown from which the wine was made, the former being three times more valuable than the latter.

In the manufacture of the better qualities of Madeira, the juice is expressed by trampling on the grapes; this is drawn off, and a further quantity of juice obtained by the action of the press on the murk, and from this an inferior quality of wine is prepared. The fermentation is usually continued for about six weeks, the juice being constantly agitated.

The juice is fermented in barrels and is then drawn off into smaller barrels or bags of goat skin. *Brandy* is mostly mixed with the must to the extent of from one half to one gallon to a Portuguese pipe. As soon as the first fermentation is complete a second addition of brandy is made, and after the lapse of three weeks it is racked off and fined, and then a third addition of one gallon of brandy takes place. In consequence this wine requires about six years for ripening. A fourth, and it is to be hoped the last, addition of brandy is made just before exportation.

Although the addition of brandy retards the maturation of wine, it is said to effectually prevent it turning ropy, bitter and sour.

The wines grown in the north of the island are mostly used for the manufacture of brandy.

For the ripening or mellowing of the wine, heat and motion are had recourse to.

One plan is to keep the wines in stores heated to about 32° C.

Another is to place the bottles, well corked, in heaps of fermenting manure.

Lastly, in some cases Madeira is sent one or more voyages to the East Indies, the heat of the climate and the constant agitation in which the wine is kept very greatly improving its qualities.

The adulterations to which Madeira is subject are in the main similar to those of sherry and other white wines. Madeira of inferior quality is mixed with and passed off for the best, and wines are fabricated in imitation of Madeira, but really not containing a drop of that wine in them. A spurious Madeira is sometimes made from a Canary wine called *Vedonia*, which somewhat resembles Madeira, and, like it, is improved by heat and agitation. This is mixed with a small quantity of *mountain port* and *Cape*, 'sweetened with *sugar candy*, flavoured with *bitter almonds*,' and then subjected to a hot-water process to give it mellowness and age.

Of course, a higher price is charged for Madeira which has been to the East Indies. Much that is sold as having undergone the voyage has never been to the East at all. It is stated that, in order to aid this deception, casks are branded and false bills of freight exhibited.

Many imagine that wines purchased at the docks *must* be pure; there is good reason for believing that this is not always so. On this subject, we find in the 'Tricks of Trade,'—the article on wine in which work is full of interesting information—the following remarks:—'The crafty importer, in general, orders his ships, on their way to England, to touch at Guernsey or Jersey, when the required adulterations are practised.'

Some idea of the extent to which Madeira is adulterated may be formed when it is known that not more than 25,000 pipes are made: of these not more than 3,000 belong to the first growth, of which only about one-half reaches this country.

CAPE WINES AND THEIR ADULTERATIONS.

Nearly the whole of the wine produced at the Cape for importation to this country is strongly *brandied* and made up in imitation of port and sherry. The imports have fallen off during the last few years to almost nothing.

'The fermented wines are *sulphured*, either by fumes or by the admixture of flowers of sulphur; freshly-killed meat is hung up in them, for who knows what purpose? Lastly they are dosed with *Cape-smoke*, so called, *i.e.* indigenous brandy.'—*Thudichum and Dupré.*

Many Cape wines are characterised by a peculiar earthy or slaty taste, due probably to imperfections in the method of preparation.

PORT AND ITS ADULTERATIONS.

The grapes from which port wine is made are trodden on a platform by men, and the juice, together with the stalks or husks, transferred to stone vats, the stalks not being separated. Port wine, therefore, possesses a considerable amount of astringency which is only in part removed as the crust forms, and as the wine ages.

After the first fermentation is over *brandy* is added, and if the must from which the wine is obtained was deficient in *sugar*, an addition of that substance is also made, as well as not unfrequently *colouring matter*. The sugar added may be either *cane*, *beet*, or *grape sugar*, but not uncommonly a portion of the must is evaporated as in the case of sherry, and the extract so procured is added to the ordinary must. When colouring matter is employed the addition is made by treading with the grapes one or other of the substances usually resorted to, as dried and powdered *elderberries* or *black cherries*. In good years grapes contain a sufficient amount of colouring matter to afford all the colour necessary, especially when mixed with a proper quantity of the tinto wine. Sometimes however, even in good years, port wine becomes of a brownish-red colour, and in such cases artificial colouring matters have to be employed, and *Jerupiga* is resorted to, but these are added at a later stage of the manufacture.

Jerupiga is a compound expressly prepared for the adulteration of port wine; it consists of *the juice of elderberries, brown sugar, unfermented grape juice*, and *brandy.*

Towards the middle of November the wine has deposited its lees; it is then transferred into pipes, and in the spring of the following year it is brought down to Oporto and Villa Nova to be there stored.

Analyses of Port Wine.

	Pure Wine Association.				Ports.	
Specific Gravity at 15·5° C.	988·8	996·3	991·3	992·3	1006.84	1001·08
Absolute Alcohol by Weight	13·308	15·166	11·230	8·625	16·17	17·75
Proof spirit	28·79	32·91	24·36	18·76	34·97	38·18
Tartaric acid	0·460	0·532	0·608	0·622	0·396	0·420
Acetic acid	0·032	0·030	0·068	0·061	0·043	0·041
Phosphoric acid	0·031	0·045	0·032	0·021	0·025	0·024
Sulphuric acid	0·021	0·046	0·042	0·016	0·016	0·020
Ash	0·189	0·294	0·230	0·275	0·253	0·260
Alkalinity of ash	0·072	0·085	0·113	0·068	—	—
Grape sugar	0·581	1·308	0·351	0·436	7·06	6·00
Total solids	2·425	4·555	2·067	2·067	7·96	7·02
Sulphate of potash, grains per bottle	5·31	10·71	10·63	4·55	4·00	5·05

According to Thudichum and Dupré, no port wine reaches England which contains less than three gallons of brandy to the pipe, but heavily brandied wines contain as much as from fifteen to seventeen gallons. The chief reason for this large addition of brandy is that it affords the quickest and most certain means of rendering the wine marketable, but not drinkable, for it really retards the maturation. The brandy stops fermentation so that the wine may be exported to any climate—and indeed it would be a strange thing if, with about 40 per cent. of proof spirit in it, it did not keep. To become mellow and sound it is necessary that the wine should be stored in bottle for six or eight years.

In addition to all the other brandyings, port wine receives one per cent of *proof spirit* on shipment.

Thudichum and Dupré state that the alcohol in natural port wine ranges from 9 per cent., the lowest, to 13·9 per cent., we presume by volume, the highest limit, equal to from 15·8 to 24·8 per cent. of proof spirit.

Jerupiga is extensively imported into this country for the adulteration of port wine. By a return made some years since to the House of Commons, on the motion of the late Mr. Oliveira, it appears that Jerupiga was imported and used by some of the first houses engaged in the wine trade in this country.

Another substance used to colour port wine, both in Portugal and at home, is *logwood*; large quantities of this dye are, it is stated, imported into Oporto.

The wines of Valencia, Bene Carlo, and Alicante, being rich in colour, are made up to imitate port wine, and the casks are prepared to resemble port pipes in size and appearance. A very large proportion of these wines, Mr. Bernard states, are sent to France to be used in the blending of other wines and in the preparation of imitation ports shipped to this country from Marseilles.

Lastly, port wines are adulterated at Oporto *by the addition of inferior wines*, imported for the purpose. It is by this means that the supply of port wine is maintained at a tolerably uniform average, no matter what may have been the vintage.

Catalan has lately been introduced into this country. It is a Spanish port wine, but is often sold as the product of Portugal.

It is therefore evident that port wine is subject to a large amount of adulteration, before it reaches this country; after its arrival here it is frequently subjected to further sophistication.

Sometimes it is diluted, brandied, and then coloured by the mixture termed Jerupiga, or by means of logwood. The brilliancy of its colour is sometimes increased by means of *alum*, and if turbid, it is cleared by *gypsum*, while increased astringency is imparted by means of *oak sawdust*. Not unfrequently peculiar flavours or bouquets are artificially communicated to port wine: the principal substances used for this purpose are *extract of sweet briar*, *orris root*, and *cherry laurel water*.

In other cases the true flavour and taste are given to factitious port by means of *a tincture made from the seeds of the grape*.

The resemblance to port is further increased by adding *salt of tartar* to the wine, which is one of the natural constituents of the grape. This salt after a time becomes in part deposited in a crystalline state from genuine port wine, either on the sides of the cask, or in the bottle in which it is kept, it carrying down with it some of the colouring matter of the wine, thus forming the crust. The fabricators of spurious port have not forgotten to imitate this criterion of a good wine.

For this purpose a hot saturated solution of cream of tartar, coloured red with a decoction of Brazilwood, is placed in the cask and rolled about in it until the sides becomes covered with the crystallised substance, after which the imitation wine is poured in. Bottles even are treated in the same manner, and the very corks are also dyed.

The crust of port wine is an indication of its age, and not only is this produced in the manner just pointed out, but likewise in other ways; one of these is to put new port into warm water, the temperature of this is raised to the boiling point, after which the wine is put back into the cellar, when it soon deposits a crust which might pass for the growth of years.

But we have not yet exhausted the list of adulterations practised upon that much-abused wine, port.

Accum states, 'many thousand pipes of spoiled cider are annually brought hither from the country for the purpose of being converted into factitious port wine.'

Another method practised of adulterating port wine is to mix together a variety of cheap red wines, adding a little genuine port. This system is exposed in a work entitled 'Wine and Spirit Adulterations Unmasked.' The author states that large vats are kept by the manufacturer in which different inferior wines are mixed together in imitation of port. These are for the most part Bene Carlo, Figueras, and Red Cape. One or more of these are mixed together, a proportion of common port added, and a small quantity of Mountain to impart a softness and give a rich appearance. Salt of tartar will ensure a quick and firm crust, and *gum dragon* gives a fulness of flavour, a consistency of body, and a good face. *Berry dye*, a colouring matter imported from Germany for the express purpose of adulteration, will increase the deep purple tint, while with washings of brandy casks the whole compound is made perfect. Wine thus made up would cost only about 16*s*. per dozen, every expense included.

Various receipts have been published for the manufacture of spurious port. The following are from the 'Publicans' Guide:'—'The cask is to be well sulphured, and then twelve gallons of strong port, three gallons of Cognac brandy, six of proof spirits of wine, and forty-two of good rough cider, making in all a compound at the rate of 18*s*. per dozen.' A second receipt is as follows:—'Take forty-five gallons of cider, six of brandy, two of a decoction of sloes, and eight of port wine. To increase the colour, tincture of red *sanderswood* or *cudbear* must be added. The wine is to be bottled in a few days, and a teaspoonful of powdered *catechu* added to each bottle to give a rough and astringent flavour and to ensure a fine crust; lastly, in order to give an appearance of age, the ends of the corks are to be stained by soaking them in a strong decoction of Brazilwood containing a little alum.'

Dr. Reece's 'Gazette of Health' contains the following receipt:—'Take of British grape wine or cider four gallons, of the juice of red beet two quarts, of brandy two quarts, of logwood four ounces, or rhatany root bruised half a pound. First infuse the logwood and rhatany root in brandy and a gallon of grape wine or cider for a week. Then strain the liquor, and mix it well with the ingredients; keep it in a cask for a month, when it will be fit to bottle.'

The following receipt for the manufacture of *Southampton Port* is from the same work:—'Take cider thirty-six gallons, elder wine eleven gallons, brandy five gallons, damson wine eleven gallons, and mix.'

It thus appears that great and scandalous tricks are played with the English gentleman's favourite after-dinner beverage.

The consumption of port wine has recently much declined—partly, doubtless, owing to its excessive strength, and partly in consequence of the knowledge of its adulteration being more extensively diffused. It is to be hoped that this result will lead to a reaction, and teach the adulterators that they are perilling the consumption of this wine in this the great port wine drinking country.

FRENCH WINES AND THEIR ADULTERATIONS.

We have obtained from the treatise of Messrs. Thudichum and Dupré, so frequently quoted before, the following information relative to the adulteration of the wines of France.

The wine made from the Grenache, in the *Roussillon* district, is manufactured in a particular manner. The grapes are carried to the press and transformed into must, and after the must has been drawn off, 2 litres of *proof spirit* are added to every 100 litres of the liquor, and the mixture is immediately put into well *sulphured* casks. A fortnight later the wine is racked, and the racking is repeated every month for about six months, till the wine remains clear. It must be left in the cask for fifteen years before it can be drunk.

The grapes in the *Roussillon* district are mashed by treading, and the berries are not separated from the stalks. The cuvage is mostly performed in barrels from which the top has been removed. The *plastering* of the must is not uncommon in this district, and contributes, in the opinion of the authors above quoted, not a little to make the Roussillon wine flat and mawkish and to deprive it of that refreshing acidity which alone makes sugary wines tolerable.

The lower classes of the *Perpignan* wines are always treated with *plaster*; and again, in the *Languedoc*, the grapes are trodden with the feet, or mashed with machines, consisting of revolving cylinders. They are ordinarily powdered over with *plaster of Paris*.

The wines of *St. Gilles* are of a brilliant purple colour, soft, of much body and strength, and they possess what the French call *nerve* and *mordant*. They are called *vins fermes*, because they can be used to give colour, strength and body to wines which do not possess those properties, and hence they have also been termed *vins de remède*.

The feeble wines of this district are fortified with *spirit*; the grapes are put into a cauldron and heated in order to macerate the hard skins and to allow the colouring matter in them to be extracted more easily. The grapes so treated are afterwards put either into spirit or into new wine. A similar means has long been adopted in the manufacture of wines in Oporto. The fermenting vats of the Languedoc are frequently after twenty-four hours deprived of a portion of their wine, which then has attained only a dark rose colour. This wine is fermented in that state and send off to the Burgogne to serve in what the French call the 'arrangement' of the Burgundy wines.

The wines of St. Gilles are most commonly used for the artificial production of port and sherry, of which not a little is thus made in Xeres itself.

'We know it for certain that a little *brandy* is added to common, very common *Bordeaux* wines. We know also that the better Médoc wines are mixed with some Hermitage to give them a little more alcoholic strength. We know as certainly that of the thousands of barriques of good and best clarets of good years not one receives a particle of brandy, but even if it did, its alcoholic strength would be nothing like that of Oporto wine.'—*Thudichum and Dupré.*

Burgundy may be classed amongst the claret wines: it is perhaps the finest of all the natural red wines; it is stronger than ordinary clarets, the strength being sometimes increased by the addition of brandy. It possesses a powerful aroma, and a delicious and lasting flavour; it is slightly astringent, and hence sometimes occasions headache and indigestion. It must be remembered, however, that as it arrives in this country it is usually brandied, and this may in some instances account for the effects produced.

The addition of *brandy* to Burgundy is most injurious to its flavour and smell. So delicate is this wine, it is said, that if two Burgundies of superior qualities are mixed together, the bouquet and taste are entirely changed.

In many parts of Burgundy the addition of *sugar* to the must is very common, in some cases amounting to as much as 20 pounds to the piece. Messrs. Thudichum and Dupré believe that much of the fieryness and alcoholicity and so-called 'headiness' of Burgundy wine, of which amateurs complain, arises from this addition of sugar and that more objectionable properties are by no means natural qualities of the general products of the Côte d'Or.

'Now comes a phase in the production of Burgundy which is unparalleled by any proceeding in any wine-producing country. The fermentation is complete and the wine has to be drawn, but it is desired to impart to the wine all the colour that can be extracted from the husks. For this purpose the husks which have been collected in the chapeau have to be thoroughly mixed with the alcoholic fluid. The top of the chapeau, which is mostly a little rotten and sour, is therefore taken off, and two or three men, having laid aside their clothes, mount to the top of the chapeau. The chapeau is so dense that the men can stand upon it for some time; each of the men works a hole with one foot through the crust; he then gets his other foot through and gradually succeeds with much trouble in causing his body to sink through the crust into the wine below. While thus engaged the whole chapeau is broken to pieces and worked together with the wine. These men now work the whole of the murk, and mix it thoroughly in all directions with the wine for about half an hour. They then emerge from the liquid covered with a dark red dye, and after wiping their bodies with the shirt they pulled off, they put on a fresh shirt and re-dress. After the lapse of several hours the chapeau is again risen as before. During this operation the men perspire profusely, not only from the intense labour which they perform, but also from the poisonous effect of the carbonic acid gas exhaled by the fermenting mass. They are mostly deadly pale or blue, and pant and hang their heads over the edges of the cuves, gasping for fresh air.'—*Thudichum and Dupré.*

CHAMPAGNE AND ITS ADULTERATIONS.

The grapes from which champagne is made are black. The process of manufacture is most carefully conducted. The grapes are first examined, every bruised or unripe berry being removed. For the grey or white champagne, the grapes are trodden for a quarter of an hour before being pressed. For the pink wine, the treading is prolonged until the juice becomes tinged with the colouring matter of the husks. For inferior champagne, the colour is sometimes artificially produced by means of a little *red wine*, or even by the juice of *elderberries.*

The white champagnes are therefore in general to be regarded as purer than the pink varieties.

Champagnes are not only classified according to their colours, but also into still and sparkling. The best of the still wines is Sillery, a dry champagne, of an amber colour, rich body, and powerful bouquet.

'It is now (December) write Messrs. Thudichum and Dupré, that the champagne-making houses send their agents about in order to acquire those particular wines of which they stand in need for mixing with the qualities which they may have themselves produced. This mixing is one of the most important operations in the production of champagne. Every manufacturer is, of course, obliged to produce the varieties which the public demand—Sillery or Epernay, others Ay; this merchant wants Mareuil, the other Dizy. There is hardly a name of any notoriety which has not its particular admirers. The object of all champagne houses is now to produce by the art of mixing wines which shall be as similar as possible to those of which they are to bear the names. When these necessary ingredients have been brought together they are mixed by vatting and then drawn off again into the barrels for further treatment.'

The wine is afterwards fined by means of isinglass, an operation which may have to be performed several times, much *sulphur* being burnt in the casks in order to render the wine as pale as possible. The wines which have been treated as above described are racked into bottles, which are filled to a height of about two inches from the top of the neck.

In the manufacturing of sparkling *hock*, young wine is mixed with old wine, usually in equal proportions, and about two per cent. of sugar added, since Rhenish wines after fermentation do not contain any sugar. In the manufacture of champagne no addition of sugar is required, as the young wines, with which they are mixed, furnish the required amount of saccharine matter.

As the summer advances the temperature of the cellars in which the wine is stored rises, and the wine begins to ferment; it so increases in bulk that the empty space in the bottle nearly or wholly disappears, many bottles beginning to leak, and others to burst from the pressure of the gas. By the autumn the temperature falls and the breakage for the most part ceases.

The next operation is the clearing of the wine, which takes place, when the wine is in a state fit for sale. This operation has for its object the removal of the yeast, which has settled on the sides of the bottles. These are placed with their necks downward so as to allow the yeast to become deposited on the cork, forming a layer in some cases of considerable thickness. The cork is now removed, and the yeast allowed to escape with the carbonic acid which immediately rushes forth, it being quickly once more corked.

The wine has now to undergo what is termed 'liqueuring.'

Champagne made as described is quite dry. The operation of liqueuring consists in imparting to it a certain amount of sugar corresponding to the taste of the consumer, and also giving to wine which has not had time to mature a certain finish and flavour by mixing with it a small quantity of good old, well-matured and fine-flavoured wine. Hence the champagne merchant who makes fine champagne provides himself with excellent wines for the purpose of making these liqueurs, and in all these cases the liqueur consists of a mixture of pure cane sugar and wine only, but the cheap kinds of champagne not admitting of the introduction of expensive wines or requiring the addition of alcohol on account of the natural want of that ingredient, are not treated with wine, but with a liqueur consisting of *wine, spirits of wine* and *sugar*.

A certain quantity of liqueur is introduced into the wine and the bottle finally corked.

It sometimes happens that a second operation of disgorging has to be performed.

Four principal varieties of champagne are made. *Champagne non-Mousseux*, both red and white: *Champagne cremant*, moderately sparkling only; *Mousseux*, and *Grand Mousseux*.

Of the champagne sold in England a very large proportion is spurious.

Sometimes it is fabricated from cheap *white French wine, sugar* and *colouring matter* being added.

At others it consists in part, or even wholly, of wine made from the *gooseberry*, and even from the *apple, pear*, or *rhubarb*.

Not unfrequently it is manufactured after the following, or some similar receipt:—'Take of *white sugar* eight pounds, the whitest *brown sugar* seven pounds, crystalline *lemon acid* or *tartaric acid* a quarter of an ounce, pure *water* eight gallons, white *grape wine* two quarts, or *perry* four quarts, of *French brandy* three pints. Boil the sugar in the water, skimming it occasionally, for two hours; then pour it into a tub, and dissolve in it the acid before it is cold. Add yeast, and ferment. Put it into a clean cask, and add the other ingredients. The cask is to be well bunged, and kept in a cool place for two or three months; then bottle, and keep it cool for a month longer, when it will be fit for use. By adding one pound of fresh or preserved *strawberries*, and two ounces of powdered *cochineal*, the pink champagne may be made.'

The champagne sold at races, fairs, and tea-gardens is rarely if ever genuine.

GERMAN WINES AND THEIR ADULTERATIONS.

Moselle is a thin wine, resembling the Rhine wines, but not possessing the same keeping qualities; it is a common practice to impart to this wine by artificial means the flavour of the wine of the muscatel grape. A tincture of the *flowers of the elder* is prepared, which is sold under the name of 'essence of muscatel,' and is much used to impart the bouquet to sparkling Moselle. Thudichum and Dupré state that there is not a grape of muscatel grown on the Moselle fit for wine-making, that there is not a single barrel of wine made there which naturally has the muscatel flavour, and that all the wine having the flavour which imitates it is made up with tincture of elderflowers. Much of the tincture is imported and sent into England and there used. Most of the 'Moselle with the muscatel flavour' is *Rhine wine* flavoured with elder flowers.

The yearly report of the Cologne Chamber of Commere, 1873, refers to the adulteration (or rectification, as it is termed) of German wines. Last year, it appears, this adulteration was carried on to an alarming extent among nearly all the vineyard proprietors of the Moselle, and among many of the makers of the Palatinate. Unsugared natural wines are now scarcely to be met with in the Moselle district, and the addition of *sugar* goes hand in hand with liberal dilutions with *water* and the usual addition of *spirit*. The mixture is fermented with grape husks; it is then styled wine. Last season 18,000 cwts. of common *potato sugar* were despatched from Coblentz up the Moselle, and considerable quantities were sent to the Upper Rhine, so that many cellars now contain more 1873 wine than the vineyards produced. Only an abundant crop can check this practice, and potato sugar should be subjected to the same tax as grape sugar.

We have been given to understand that Bingen is a great centre for the adulteration of Rhine wines. The must is there frequently diluted and sugared, *glycerin* being also much used.

GREEK WINES AND THEIR ADULTERATIONS.

Of Greek wines the quality varies greatly according to the source and method of vinification adopted, but this in many parts is exceedingly imperfect, 'so that the wines contain more volatile, *i.e.* acetic, acid, than any others which we have met with. Many wines last only through the winter, and in summer turn into vinegar. To avoid this result the proprietors still adopt all the horrid preservatives of antiquity, smoking with *wood smoke*, or vapour of *resins*, such as *mastic*, *olibanum*, *cloves*, *Rhodus wood*, *Buchari-Jagh*, and *libdanum*. The Commendaria (Cyprus) wine is said to get its flavour from these resins, gums and spices, which are suspended in the wine, enclosed in a bag; pitching the barrels, adding *turpentine* and real *pines*; *gypsum*, *chalk*, *salt*, and *tannin*, particularly in the form of *hypericum perfo-*

ratum, a resino-tannous plant, which is said to conserve and colour wine yellow. Most wine has also the addition of taste and smell of the goat, in the hides of which it is kept or transported. In Cyprus and other parts jars are still in use, but in Santorin and other islands barrels are becoming more frequent.'—*Thudichum and Dupré.* The wines produced in the Ionian Islands are all stated to be *plastered.*

AUSTRALIAN WINES.

The cultivation of the vine is gradually extending in New South Wales, the climate of many parts being exceedingly well adapted to its growth. Many of the wines are distinguished by their strength, robustness, flavour, and bouquet, and are really excellent.

That the soil and climate of Australia are highly favourable to the growth of the vine is unquestionable. The climate is sunny and dry; the soil ferruginous, iron being an important constituent of a vine-bearing soil. In the year 1870, nearly two million gallons of wine were made in Australia, part of which was imported into this country.

The following analyses were made by ourselves a short time since.

	Red Wines.						White Wine.	
Specific gravity at 15·5° C.	993·3	999·4	990·1	987·4	991·6	992·6	991·3	990·5
Absolute alcohol by weight	12·57	13·44	12·00	14·44	10·80	9·50	14·40	10·80
Proof spirit . . .	27·26	29·04	26·00	31·26	23·44	20·63	31·18	23·44
Grape sugar . . .	—	0·29	—	—	0·1	0·06	0·05	0·03
Total acid, as tartaric .	0·81	0·94	0·64	0·48	0·71	0·67	0·83	0·75
Acetic acid . . .	0·18	0·20	0·09	0·07	0·10	0·19	0·18	0·10
Phosphoric acid . .	0·048	0·039	0·048	0·032	0·025	0·018	0·034	0·038
Bitartrate of potash . .	0·062	0·143	0·040	0·034	0·068	—	0·093	0·081
Total solids . . .	2·65	3·32	2·19	2·01	2·41	1·43	2·26	1·79
Ash	0·24	0·24	0·25	0·26	0·28	0·24	0·22	0·15
Alkalinity of ash . .	0·18	0·14	0·19	0·19	0·19	0·18	0·06	0·099

For further particulars in reference to these wines, see reports in the 'Lancet' by the author.

THE DETECTION OF THE ADULTERATIONS OF WINE.

We have already entered very fully into the questions of the composition and analysis of wine. We have in this place, therefore, only to give the processes for the detection of the principal substances employed in its adulteration. These are *cane sugar*, *spirit*, the juice of fruits other than the grape, as of *rhubarb*, *gooseberries*, *apples* and *pears*; *colouring matters*, as those of the *elderberry*, *black cherry*, *bilberry*, *logwood* and *Brazil wood*, *cochineal*, *mallow flowers*, *sulphuric acid*, derived from plastering and sulphuring; *carbonates of soda* and *potash*, and *lead*.

Detection of cane sugar.—The cane sugar, when added to the must of grapes or to the wine itself becomes quickly transformed into glucose, and hence its detection is often a matter of impossibility. But, if only recently added to wine, there may not have been time for its transformation into glucose, and in this case it may be discovered in the usual manner by conversion into glucose by means of dilute sulphuric acid, as already before more than once described.

We have ourselves frequently met with cane sugar in Hambro' and other imitation sherries.

Detection of extraneous spirit.—Provided the spirit added has been well rectified, it is impossible to distinguish it from that natural to the wine, and hence we are only able to pronounce that the wine has been fortified when the amount present exceeds that which the must itself is capable of furnishing. This amount varies, as we have already seen, with the kind of wine and within certain limits with the same wine.

The highest amount which even the richest must is capable of furnishing rarely, if it ever, exceeds 28 per cent. of proof spirit, but it is not at all a common thing for this amount of spirit to be contained in any natural wine, though in some cases and in certain wines this quantity is reached.

Even if the must were rich enough to permit of the formation of a higher amount of alcohol, it could not do so, since fermentation is stopped in any liquid containing 15 per cent. of absolute alcohol by volume, equal to 26·66 per cent. of proof spirit.

If the spirit added were very impure, and a large quantity of wine were operated upon, it might be detected by careful distillation and rectification.

Detection of juice other than that of the grape.—No certain or satisfactory methods have as yet been devised for the detection of foreign vegetable juices after they have undergone fermentation, and especially when admixed with the fermented juice of the grape. It is quite within the range of probability, however, to suppose that satisfactory methods of discrimination will ultimately be devised.

Rhubarb, as is well known, contains a considerable amount of oxalate of lime, and hence if in the lees of any wine, particularly champagne, the characteristic octahedral crystals of this salt were seen by means of the microscope, the presence of rhubarb might with tolerable certainty be inferred.

The principal acid of the *gooseberry* is malic acid, whereas that of the grape is tartaric acid. Now, in those cases in which we have to deal simply with a wine the produce of the grape, and with one made from gooseberry juice, the discrimination would be easy enough by determining the nature of the principal acid present in each case, and by, as far as practicable, the estimation of their amounts.

But the difficulty of discrimination would of course be greatly enhanced when the two wines are blended together, and it will be still further increased in those cases in which the wine had been subjected to the operation of plastering as well.

The acid of *apples* and *pears* is the same as that of gooseberries, and therefore by it one could not distinguish whether the admixture consisted of gooseberry or apple wine, but we believe that the discrimination might be effected by the aroma and flavour of the warm extract of the wine, or better still by the odour of the alcoholic distillate, which would contain the very characteristic volatile constituents of the apple and pear: apples contain a notable quantity of a peculiar and distinctive oil, termed apple oil. We believe that the odour of the warm extract will in many cases afford a clue to the vegetable substances employed in the sophistication of wine. Thus the smell of elderberries is in some cases quite recognisable.

According to F. F. Mayer, wine made from fruits, as apples or pears, contains phosphate of lime, while grape wine contains phosphate of magnesia. If to about nine parts of wine one part of ammonia be added and the mixture be allowed to stand for twelve hours, cider and perry deposit tabular crystals which firmly adhere to the sides of the glass, while grape wine gives a precipitate which does not adhere to the glass, and is found under the microscope to consist of small stellar crystals of ammonio-phosphate of magnesia. According to Mayer a mixture of one part of perry and three parts of grape wine still gives the crystals characteristic of cider or perry, but it may be doubted whether all wines behave in this manner, and whether phosphate of magnesia is a constituent of all genuine wines.

Detection of colouring matters.—The satisfactory detection of these, especially when found in wine, and when their properties have been altered by keeping, perhaps for many years, constitutes one of the most difficult of tasks, even when we bring to our aid spectrum analysis.

Very much has however been written on this subject, of more or less value. In some cases the attempts at discrimination are of a general character, and are directed to the object of simply ascertaining whether the wine contains any other red colouring matter than that derived from the grape. In other cases efforts have been made to identify the particular colouring matter employed.

We will now proceed to give, in as brief a form as possible, the more important particulars which have hitherto been made known.

Method of M. Vogel.—This chemist has recommended acetate of lead for the detection of extraneous colouring matters in red wine. With this reagent he states that genuine red wine gives a greenish grey precipitate, but that in the case of wine coloured with the juice of *bilberries, elderberries,* or *Campeachy wood,* the precipitate is deep blue, while with *Brazilwood, red sanders,* and *beet,* it is red. Wine coloured with beetroot is also rendered colourless by lime water, but the weakest acid brings back the colour.

According to Berzelius, the colouring matter of red wine gives different coloured precipitates with diacetate of lead, according to the age of the wine, and that in new red wine the precipitate is generally blue. If this is correct, the value of the test of Vogel is of course much diminished.

Berzelius's statement seems opposed, however, to the following experiment of Vogel. It has already been remarked that the colour of red wines is derived from the colouring matter located in the skins of the grapes. In order further to assure himself, he prepared a quantity of grape skins, reduced them to powder, and treated them with alcohol. This took up part of the colouring matter, and when acetate of lead was added, the same greyish green precipitate was obtained. Lastly, it should be stated that the wines principally experimented upon by Vogel were new wines, and were made by himself from black grapes for the purpose of his experiments.

Mitchell states that the precipitate with acetate of lead from an infusion of *logwood* is purple red, and that if the colouring matter be very much diluted it has a leaden or bluish hue. With the juice of beet the colour is puce; when diluted with water the tint becomes a pale salmon red.

Method of Chevallier.—Solution of caustic potash, added to genuine red wine in such quantity as to neutralise all the acid, causes the colour to change from red to bottle green, and after some time to brownish green, but no precipitate is formed. The colours produced when foreign colouring matters have been employed are different, as shown in the following table:—

Wine coloured with—	Colour produced by Potash—
Elderberries	Purple.
Logwood	Reddish purple.
Red mulberries	Purplish.
Brazil wood	Red.
Beetroot juice	Red.
Litmus	Light violet.

Method of Jacob.—The colouring matters experimented upon were those of the petals of the poppy, logwood, and Brazilwood. The reagents which he employed were sulphate of alumina and carbonate of ammonia.

Normal wine furnished a slightly coloured *greyish* precipitate. The same wines, with *Brazilwood,* gave a *carmine red* precipitate which varied in intensity with the quantity of colouring matter added; with *logwood* the precipitate was of a fine *deep violet colour,* and with *red poppy* of a *slate-grey* colour.

The reagents were thus employed:—A solution of sulphate of alumina was made, containing 10 parts of the salt to 100 of water; about half a drachm of this solution was added to an equal quantity of wine, and then about 12 to 13 drops of a solution containing 8 parts of carbonate of ammonia to 100 of water. A precipitate of alumina was immediately produced, variously coloured, according to the nature of the colouring matter employed. An excess of the precipitant must not be added, for in that case the tints produced are not sufficiently marked to allow of the discrimination of the substance employed. The action is most marked after the lapse of seven or eight minutes.

Method of Nees Van Esenbeck.—The process of Nees Van Esenbeck is but a modification of the preceding method, that chemist using alum and carbonate of potash.

These reagents, with *normal wine,* give a dullish grey precipitate having a more or less decided red tinge. An excess of alkali redissolves part of the precipitate, the remainder being ash grey. If the wine be new, the residuary precipitate possesses a greenish tinge.

Wine coloured with the colouring matter of the petals of *red poppy* gives a brownish grey precipitate which becomes black by excess of alkali.

Coloured with *privet berries,* it gives a brownish violet precipitate.

Coloured by *elderberries,* a violet precipitate; by *Brazilwood,* a greyish violet; and by *logwood,* a rose-coloured precipitate.

It therefore follows, from the experiments of Nees Van Esenbeck, that all those wines, which give with the reagents above named bluish violet or rose-coloured precipitates, are artificially coloured or adulterated with foreign colouring matters.

The reagents must be employed by means of solutions of definite strength—namely, one part of alum to eleven of water, and for the other solution one part of carbonate of potash to eight parts of water; the wine and the alum solutions are to be mixed together in equal proportions, and the solution of potash gradually poured in, until the whole of the alumina is precipitated.

Method of Cottini and Fantoggini.—For the discrimination of genuine red wines and artificially coloured red wines Cottini and Fantoggini recommend ('Annali di Chimica appl. alla Medicina') the addition to 50 cc. of the wine to be tested of 6 cc. of nitric acid of 42° Baumé, and to heat the mixture from 90° to 95° C. Natural wine, they state, is not altered by this treatment, even after the lapse of hours, but artificially coloured wines are said to lose their colour within five minutes.

But F. Sestini has shown ('Landwirthschaftliche Versuchsstationen,' 15. 9), that the above statement hold goods only with the wines of Tuscany, and that the red wines of France and of the Romagna of undoubted genuineness are also quickly decolorised by nitric acid.

Method of Duclaux.—E. Duclaux has published (Comptes rend.) methods for the discrimination of genuine red wine from that coloured with the colouring matter of the *flowers of the mallow,* with that of the *kermes insect* (*coccus ilicis*) and of *cochineal.* For detection of the first, he makes use of the fact that the colouring matter of the wine becomes insoluble by the action of oxygen, while that of the mallow is rendered more easily soluble.

For the detection of cochineal Duclaux recommends the spectroscopic examination, proposed by Phipson.

For the discrimination, lastly, of the kermes from genuine red wine, he adds a little piece of sodium amalgam to the wine. Genuine wine is said to remain unaltered, or to change only very slowly, whilst that coloured with kermes immediately loses its colour.

Method of Boyer and Coulet.—F. Boyer and H. Coulet (Compt. rend. 76) propose to make use of wool dyed yellow by means of chromate of potash. Such wool, boiled for some time with genuine wine, assumes a characteristic light-brown colour, no matter in what country the wine is grown, while, if the wine be artificially coloured with aniline dyes, especially with *fuchsin*, the wool is dyed red.

Wine coloured with *cochineal* does not change the tint of the wool, but extract of *Brazil wood* gives rise to a dark wine red, and extract of *Campeachy wood* to a brown or brown-black colour. A mixture of Campeachy and of Brazil wood extract, dyes the wool from iron-grey to black.

Method of Shuttleworth.—E. B. Shuttleworth ('American Journ. of Pharm.' 4) recommends for the detection of extraneous colouring matters in port wine the spectroscopic examination and the employment of amylic alcohol, first recommended by Giuseppe Romei. The colouring matter of genuine port wine is not dissolved by fusel oil, and if, therefore, on shaking the wine with some amylic alcohol this is coloured red, extraneous colouring matter has been employed.

Method of Dietrich.—E. Dietrich ('Archiv. der Pharm.') has studied the behaviour of dilute genuine red wine and that coloured artificially towards acetate of lead, sulphate of copper, and baryta water. He employed 10 per cent. solutions of these substances and dilutes the wine with 20 times its bulk of water. Genuine wine by these reagents is rendered quite colourless, a feeble turbidity being produced, but artificially coloured wine assumes a violet blue or green-blue colour. Dietrich, however, omits to state what the wine he experimented upon was coloured with.

Spectroscopic discrimination.—Mr. Sorby, as is well known, has applied the spectro-microscope to the discrimination of various colouring matters, particularly those employed in the artificial coloration of wine.

'The pure colour of fresh dark grapes is best prepared by removing the skins, heating them in alcohol, evaporating the solution to dryness, redissolving it in a little water, filtering, and again evaporating to dryness in a small saucer, in which the colour may be kept as a stiff syrup without material change.'

One of the peculiarities of the colour thus prepared is its tendency to pass into insoluble modifications.

The solution of the colour of fresh grapes prepared as above directed, which has not been previously evaporated, fades very rapidly and becomes nearly colourless; but when this solution is evaporated to dryness, or if some strong acid be added to it, the original colour is restored. To obtain the same depth of the spectrum of the faded and of the unchanged solution, it is necessary that the stratum of the first should be about five times as thick as that of the latter.

If some hypochloride of soda be added to the newly-prepared solution it then gives the same spectrum as wine after fermentation, and if more hypochloride be added, the colour of the wine becomes much lighter, and the spectrum is then identical with that of wine kept in cask for many years. It appears, therefore, that the colour of old wines is lighter than that of the newly-prepared grape juice, because the colouring matter is altered by oxidation.

By this change of colour and by the consequent altered position of the absorption band in the spectrum, Mr. Sorby affirms that he is enabled to judge of the age of a red wine within certain limits—the position of this band being more and more towards the violet end of the spectrum the older the wine.

Mr. Sorby states that the only cases in which the spectrum method can be easily applied to the detection of foreign colouring matters in wine are those in which the wine is mixed with *logwood*, *Brazil wood*, *Rhatany root*, and the *berries* of the *Virginian Poke* (*Phytolacca decandra*); he declares, however, that he has not detected these substances in any wines of commerce that he has as yet examined.

For the detection of *logwood* or *Brazil wood*, the wine is treated as follows:—it is agitated with ether, which remains quite colourless if those colouring matters be not present, but becomes more or less deep yellow if either has been added. The ethereal solution is evaporated to dryness, the residue dissolved in a solution of carbonate of ammonia, when the liquid is ready for observation.

'In both cases this develops a single very distinct absorption band in the green, that characteristic of logwood being situated at $4\frac{3}{8}$ of my scale, while that of Brazil wood is further from the red end, at $5\frac{1}{4}$, and the solution is strongly fluorescent, of a peculiar orange colour. These spectra are so characteristic and can be so easily compared with those of the substances themselves, that an extremely minute quantity of either would be detected with certainty.'

Rhatany root may be detected by evaporating the wine nearly to dryness and exhausting the residue with alcohol. The solution is poured off, and after it has become quite clear it is examined with the spectroscope. There is a moderately distinct band at $3\frac{3}{4}$ of Sorby's scale, and a fainter at $7\frac{1}{4}$.

The berries of the *Virginian Poke* contain a colouring matter which is characterised by a band at $4\frac{5}{8}$ and one at $7\frac{5}{8}$, both of which are more distinct in alcoholic solution than when dissolved in water.

'These substances may be changed by keeping long in solution, and therefore might not be detected in old wines.'

For fuller details the reader is referred to vol. xv. p. 432, of the 'Proceedings of the Royal Society,' and to vol. xxxvi. p. 358, of the 'Quarterly Journal of Microscopical Science.'

It is strange that Mr. Sorby makes no reference to elderberries, the colouring matter of which is so commonly added to the red wines, especially port.

Genuine port wine, according to Thudichum and Dupré, gives a spectrum showing a broad absorption band in yellow, and a continued absorption of the blue and violet, but the juice of *elderberries* gives a spectrum showing a narrow absorption band in red and two absorption bands in blue. Every port wine or other wine yielding this spectrum has been dyed with elderberry, but the absorption bands are lost to a great extent as the wine becomes aged.

Detection of sulphuric acid.—The total amount of combined sulphuric acid present in the wine is to be determined in the usual manner, and calculated for sulphate of potash. From the amount of this salt present a deduction of 36 grains per gallon is to be made, this being the full quantity of sulphate of potash ever likely to be present in any wine made from the grape only.

Detection of carbonates of soda and potash.—When these alkalies are added to wine with a view to diminish the acidity, they are of course decomposed, tartrates of soda and potash being formed. We therefore should obtain the ash of 50 cc. of the wine, and make the usual quantitative determinations of the alkalies, comparing the amounts with those found in the ash of genuine wine.

Detection of lead.—Processes for the detection of this metal will be found described in the articles on 'Water' and 'Vinegar.'

Soleras.

'The best wines,' according to Thudichum and Dupré, 'which come under the description of vino fino, Amontillado and Manzanilla are used for the production or keeping up of *soleras*. A solera is a thing kept by itself; a solera wine is a choice old cabinet article.' Soleras are not used for drinking but for blending with other kinds to give them the character of age and ripeness, and otherwise to improve their flavour and qualities. These wines are kept in stock in butts from year to year, the proprietor drawing off a portion of the stock for mixing with wines about to be exported, and making up the original quantity by an addition of an equal amount of the finest wine of a later vintage which he can obtain. Solera wine is therefore a mixture of several kinds, but the special peculiarity is, that these mixed wines undergo and induce, the one from the other, a process of speedy etherification. According to Thudichum and Dupré, 'the process becomes so potent in some soleras, that they are absolutely nasty and undrinkable, like most essences, but command prices from 800*l.* to 1,000*l.* per butt on account of the large quantity of flavourless wines, which a certain small amount of them is able to infect with the desired sherry flavour. The solera wine is thus seen to correspond to the liqueur used in the manufacture of champagne.'

CHAPTER XLVI.

SPIRITUOUS LIQUORS AND THEIR ADULTERATIONS.

Alcohol is the principal and most valuable constituent of all fermented beverages, as of beer, wine and spirits, beer containing only a very moderate amount, wine a medium quantity, but spirits most of all, the variation in the amount ranging from 3 per cent. as in the case of weak beer, up to over 50 per cent. as in that of undiluted spirits.

Alcohol is formed from all liquids subjected to fermentation with yeast or other nitrogenous substances, which either contain *sugar* or which by special treatment are capable of furnishing that substance, as *starch* and *woody fibre* under the influence of diastase or dilute sulphuric acid. It does not matter what the kind or source of the sugar may be, as *glucose*, under which are included *dextrose* and *lævulose*, *milk sugar* and *cane sugar* all furnish alcohol, milk sugar being converted prior to its transformation into *galactose*, and cane sugar into *glucose* in the form of *invert sugar*, which is a mixture of dextrose and lævulose.

At the same time that the alcohol is formed from the sugar, *carbonic acid* is likewise generated; the formula whereby these decompositions are represented is as follows:—

$$\text{Glucose, } C_6H_{12}O_6 = 2\ C_2H_6O\text{, Alcohol, } + 2\ CO_2\text{, Carbonic acid.}$$

But since the various infusions, as of unmalted grain, malt, potatoes, sugar, molasses, the juice of fruits, as of the apple, pear and grape, contain a variety of other substances besides the sugar or matters convertible thereinto, when these liquids after fermentation are subjected to distillation a number of other volatile products besides the alcohol pass over into the receiver.

Thus in the case of molasses *butyric ether* is produced in quantity sufficient to impart to the rum much of its characteristic aroma; in that of the grain and potato, *fusel oil*, which also gives to the spirit its peculiar flavour, odour and other properties, and in the case of wine and brandy *œnanthic*, as well as some other ethers, in minute quantities.

Now of these volatile substances some are very valuable constituents of the products of distillation, as the œnanthic ether in brandy, but others are objectionable on account of their smell and injurious properties, and have in some cases to be removed, as tho fusel oil of grain and potato spirit, where an alcohol pure or nearly pure is required, and hence recourse is had to the operations of *rectification* and *defuselation.*

By the first distillation of any fermented liquor the alcohol which passes over is diluted with a very large quantity of water, from much of which it has to be freed by fractional distillation, and where absolute alcohol is required by *dehydration* with chloride of calcium, caustic lime, or carbonate of potash.

Although in the present article we propose to treat only of brandy, rum and gin, yet a variety of other spirits are made and extensively consumed in various parts of the world, as the *arrack* of the Hindoos, made from rice or the araca nut; the *rakki,* also made from rice, of the Turks; the *sam-shoo* of the Chinese, from the same grain; the *toddy* of the Hindoos, from the cocoa-nut; the *pulque* of the Mexicans, from the algave: the *chica* of the South Americans, from maize; the *koumiss* of the Tartars, from mares' milk; the *vodky* of the Russians, from the potato, and the *tallah* of the Abyssinians, from millet.

Alcohol.

Alcohol in its pure state is probably perfectly odourless; it possesses a burning taste, is quite colourless, and very mobile. According to Kopp its specific gravity at 20° C. is 0·792, at 15·5° 0·7939, and at 0° 0·8095; it boils at 78·4° C. In its anhydrous state it acts as a poison, it attracting water from the membranes in the same manner, though in a less degree, as oil of vitriol. This property is made use of in the preservation of animal structures.

Alcohol as yet has not been reduced to the solid state; at very low temperatures, however, it becomes viscid.

When the vapour of alcohol is passed through a red hot tube filled with pumice stone, a great variety of products of decomposition are formed, amongst which are *water, hydrogen, marsh gas, olefiant gas, naphthalin, benzol and aldehyde.*

When burnt in the air it yields only *carbonic acid* and *water,* but when the access of the air is limited, *aldehyde, acetic acid, formic acid,* and other products are formed. Concentrated nitric acid decomposes alcohol with the formation of *nitrate of ethyl* (nitrous ether), but some *aldehyde, acetic, formic, saccharic, oxalic, glyoxylic* and *glycollic acids* are also produced.

Strong sulphuric acid combines with alcohol, forming *sulphovinic acid,* or *ethyl-sulphuric acid.* When one part of alcohol is mixed with two parts of strong sulphuric acid and the mixture heated to boiling, *sulphuric* or *ethylic ether* ($C_4H_{10}O$), passes over; but when three or four parts of sulphuric acid are employed and heated to 160 or 180° C, olefiant gas is evolved.

Now since olefiant gas is an important constituent of coal gas, it has been proposed to manufacture alcohol from this gas, by passing it through concentrated sulphuric acid, to dilute the solution thus obtained, and to distil the mixture, when alcohol passes over. At the present time, however, this method is much too expensive to be practically employed.

Preparation of Absolute Alcohol.

It has already been said that the greater part of the water which passes over with the spirit in the first distillation is separated by subjecting the mixture to repetitions of the process, but the spirit obtained in this manner will still retain some 8 or 9 per cent. of water, the complete removal of which may be effected by the aid of the chemical substances already enumerated. Other substances sometimes used for the same purposes are acetate of potash and sulphate of copper. Absolute alcohol is best prepared as follows:—

Well-dried chloride of calcium is added in thick lumps to spirit of 90 per cent., and the mixture is allowed to stand in a well-closed vessel, it being shaken from time to time. After a few days about two-thirds of the liquid are distilled off, and if necessary treated with chloride of calcium a second time.

When a bladder is filled with alcohol containing water, the water evaporates through the bladder, absolute alcohol at length only remaining.

The specific gravity affords the readiest means to ascertain whether the alcohol is absolute or not, but the presence of water may also be detected by the addition of some white dehydrated sulphate of copper; if this turn blue by the absorption of water, the alcohol is not yet absolute.

Fusel Oil.

In distilling the fermented liquids prepared from a variety of substances, as from various descriptions of corn, potato, and grapes, especially the murk of grapes, various volatile bodies besides ethylic alcohol pass over, and since most of these have a higher boiling point than alcohol, they come over chiefly with the later portions of the distillate.

These volatile substances have received in the aggregate the name of *fusel oil,* but this really possesses a very complex composition, differing somewhat in flavour, taste, and composition, according to the source from which it is obtained. The odour is heavy, penetrating, and disagreeable, and the taste fiery and nauseous. It always contains *ethylic* and *amylic* alcohols, and also *fatty acids* and *ethers,* and frequently other lighter members of the monatomic alcohol series.

The oil from the potato consists almost entirely of amylic and ethylic alcohols, the former constituting the greater part, and the latter being capable of separation by agitation with water. Sometimes potato fusel oil is found to contain in addition *tetrylic* or *butylic alcohol,* $C_4H_{10}O$.

The oil obtained from the murk of grapes has been ascertained to yield *tritylic* or *propylic alcohol,* C_3H_8O.

Fusel oil from Hungarian wines has been analysed by F. Grimm, and was found to consist chiefly of amylic alcohol with a little ethylic alcohol, but no propylic or butylic alcohol. The chief acid was caproic with a little caprylic, and a very minute quantity of œnanthylic acid, but no pelargonic acid.

In most kinds of fusel oil several members of the fatty acid series are met with; *capric acid* in the form of *caprate of amyl* has been found in the oil from Scotch distilleries. In the residue obtained in the preparation of alcohol from wheat and maize, Wetherill found *acetic*, *caprylic*, *formic*, *caproic*, and *œnanthylic acids*. Johnson has detected *capric acid* in potato fusel oil. Mulder has found *palmitic* and *œnanthic* acids, a very small quantity of *œnanthic* ether, and an unsaponifiable *waxy body* in the fusel oil from rum.

Fehling obtained from the fusel oil of beet molasses not only several volatile fatty acids, but *a neutral fat*, which when heated gave off the odour of *acrolein*, and which when saponified yielded *capric acid*.

Perrot found in the fusel oil procured from the same source various alcohols and ethers, as also a substance in the form of *a fetid liquid*, having the formula $C_6H_{10}O$, which distilled over at about 200° C.

Although some of the fusel oil passes over with the alcohol, yet as it has a higher boiling point than alcohol much of it remains behind in the retorts, as also some acetic acid produced by the oxidation of the alcohol.

A portion of the acetic acid, however, passes over with the alcohol, and this may be separated by distillation with carbonate of potassium, but the fusel oil is more difficult of separation, and is best removed by means of bone black or animal charcoal.

Properties of fusel oil.—Dr. Taylor remarks of fusel oil, that 'in small quantities it produces intoxication. I have experienced the effects of the vapour, and found them to be giddiness, accompanied with a feeling of suffocation and a sense of falling. Headache followed which lasted for half an hour.

'Two drachms of the oil killed a rabbit in two hours, three drachms in an hour, half an ounce in a quarter of an hour, and one ounce in four minutes.'

Much of the unwholesomeness of spirit imperfectly rectified arises from its contamination with fusel oil.

Detection of fusel oil.—When the nose is applied to spirits in its hot state containing fusel oil, the vapour of the oil irritates the eyes and nostrils; it has very nearly the same smell as an alcoholic solution of cyanogen, as may be perceived by standing near the discharge-pipe of the refrigeratory worm of a raw-grain whisky still. Spirits contaminated with fusel oil intoxicate more strongly than pure spirits of the same strength, and excite, in many persons, even temporary frenzy.

If one part of hydrate of potash, dissolved in a little water, be mixed with 150 parts of spirits, and the mixture be well shaken, then slowly evaporated down to 15 parts, and mixed with 15 parts of dilute sulphuric acid in a well-corked phial, there will soon exhale from the mixture a peculiar offensive odour characteristic of the quality and origin of the impure spirit, whether obtained from raw grain, from malt, potatoes, rye, arrack, rum, brandy, &c. This process may be used also for testing wines.

The Defuselation of Alcohol.

The separation of the fusel oil invariably contained in all crude spirits obtained by distillation is a matter of considerable importance and difficulty, since fusel oil imparts to spirit a peculiarly unpleasant taste and smell.

Although the boiling points of ethylic and amylic alcohols are widely different, namely, 78·4° C. and 132° C., it is not possible to separate the two alcohols by fractional distillation, since fusel oil evaporates to a considerable extent even at ordinary temperatures.

The absorbing power of *wood charcoal* is the means most generally made use of in the defuselation of spirits. The charcoal should be recently ignited and reduced to a fine powder. The spirit must be allowed to filter slowly through it, but frequently the charcoal is directly put into the still, where it retains a part, but by no means the whole, of the fusel oil. A better method of separation is to pass the vapour of the spirit before condensation through a stratum of wood charcoal.

The employment of a layer of *dioxide of manganese*, besides the use of charcoal, the addition of *slaked lime* and of *soap-boiler's lye* have all been recommended. A solution of *chloride of lime* added to the spirit before rectification is frequently employed. *Chloride of zinc* and *chloride of calcium*, as also *sulphate of copper* decomposed by caustic potash, have been proposed. Lastly, Hunefeld recommends *manganate of potassium*, but this acts both upon the ethylic alcohol and upon the fusel oil, the spirit having imparted to it a disagreeable flavour.

Milk has been employed for the defuselation of spirits. Breton recommends *olive oil*, which is said to absorb the amylic alcohol. *Soda soap* is capable of retaining 20 per cent. of its weight of fusel oil.

By cooling the spirit to be freed from amylic alcohol to −15° C. the fusel oil falls to the bottom and may be separated.

The Physiological Action of Alcohol.

The question is as yet by no means settled, whether alcohol when taken into the system is absorbed without alteration and eliminated undecomposed, or whether any is decomposed and oxidised in the blood. It is certain that the urine of persons who partake freely of ardent spirits contains large quantities of alcohol, which may be separated by distillation, the distillate being in some cases inflammable. The opinion, however, which was formerly entertained, that the alcohol accumulates in certain organs, as in the liver and brain, seems to be without foundation. The experiments of Dr. Percy, Strauch, Masing, and others seem to show, that all the alcohol is eliminated as such, whilst Schulinus and Anstie affirm that a part disappears in the system.

When taken in small quantities, alcohol aids digestion, but the habitual use of larger amounts induces a thickening of the connective tissue between the glands of the stomach, and even disappearance of the glands. It causes enlargement of the liver, and, when injected into the portal vein, augments the quantity of sugar. Alcohol lessens the secretion of carbonic acid through the lungs, and also the eliminating power of the kidneys, whilst it increases at first the force of the action of the heart, but eventually it depresses the action by paralysing the vaso-motor nerves.

On the nervous system alcohol acts as an anæsthetic, diminishing and even suspending thought, and the action of the senses. Although in some cases it is said that the senses are sharpened by it, yet the experiments of Edward Smith show that this is not the case. In moderate doses alcohol causes a feeling of comfort and exhilaration, but different spirits behave very differently in this respect, probably in consequence of their containing different ethers and volatile oils. Thus sam-shoo and rakki cause great excitement, followed by torpor and depression, while absinthe is very hurtful.

The voluntary muscular power is greatly lessened, especially by the consumption of large quantities of ardent spirits, and in very large doses the respiratory muscles or the nerves in connection with them are paralysed, and thus death is not unfrequently caused. The temperature of the body is considerably depressed by large doses of alcohol, and this is abundantly proved by the evidence of Arctic explorers, as Sir John Richardson, Mr. Goodsir, Dr. King, Captain Kennedy, Dr. Kane, and others, who found the use of alcohol under the influence of great cold to be particularly hurtful.

'Alcohol appears to decrease strength and impair nutrition, by hindering oxidation, and, if in large quantities, the reception of food; while habitually taken in any large quantity, it leads to degeneration of the tissues of certain organs, especially of the liver, the nervous system, the heart, lungs, and kidneys.'—*Parkes.*

Methods of Estimating the Quantity of Alcohol present in any Spirituous Liquid.

Saccharometers, &c.—There are several methods by which the amount of alcohol contained in any spirituous liquid may be determined with greater or less accuracy. One of the readiest of these means is to ascertain the specific gravity of the spirit by a specific gravity instrument for liquids. Of these instruments, many different kinds have been invented, with scales adapted to the range of the liquids for the determination of the density of which they have been constructed: thus we have *saccharometers, hydrometers, alcoholometers*, &c.; but the principle on which these instruments are constructed is alike in all cases. By the *saccharometer* the amount of extractive matter in beer or other alcoholic liquids is ascertained.

Sykes' hydrometer.—The instrument in general use for determining the specific gravity of spirituous liquids in this country is what is known as *Sykes' hydrometer*. It differs from the ordinary hydrometer in the division of its scale, and also in the use of weights. The hydrometer is calculated to show the strength in spirit either above or below a certain fixed standard, denominated 'proof.' Proof spirit is defined by Act of Parliament to be 'such as shall, at a temperature of 51° of Fahrenheit's thermometer, weigh exactly $\frac{12}{13}$ parts of an equal measure of distilled water.' That is to say, 13 measures of proof spirit weigh as much as 12 measures of water. The stem of the instrument is graduated and subdivided so as to meet the extremes of variation in the strength of the liquors examined by it.

Sykes' hydrometer is the instrument mostly used by the Excise, by brewers, distillers, and publicans.

Since the specific gravity of a spirituous liquid is subject to great variations at different temperatures, it is necessary that the temperature of the spirit at the time of taking its weight should be noted, and corrections made for this by means of certain tables which have been constructed for the purpose. The standard temperature at which the specific gravity of the spirit is usually taken is 60° Fahrenheit, equal to 15·5° C.

The specific gravity test for determining the amount of alcohol present in liquids is applicable only when they are free from any solid substance, as extractive, sugar, &c., the presence of which of course influences the gravity. When, therefore, any liquid contains saccharine or other solid matter, it is requisite that the spirit should be separated by distillation, and that the quantity and specific gravity of the alcohol thus obtained should be taken. Where strict accuracy is required, it will be necessary to have recourse to distillation in almost all cases, since there are but few spirits which do not contain more or less solid matter.

Centesimal alcoholometer.—The instrument, invented by M. Gay-Lussac many years since, called the *centesimal alcoholometer* is a considerable improvement on Sykes' hydrometer. The instrument, when immersed in any spirituous liquid at the temperature of 15° Centigrade, equal to 59° Fahr., at once indicates the quantity of alcohol by volume present. As its name implies, the stem is divided into a hundred parts or degrees, and is so contrived that each degree represents one-hundredth part of anhydrous or pure alcohol; thus the point at which it floats, when immersed in any spirit at a certain temperature, indicates the percentage of absolute alcohol contained in that spirit. The value of this instrument is that it shows at once the percentage of alcohol—

all subsequent calculations, with the loss of time involved and the possibility of inaccuracies, being thereby avoided.

Ebullioscope.—Another instrument, constructed on a totally different principle to the ordinary densimeters, is the *ebullioscope* or *ebullition alcoholometer*. This instrument is based upon the fact that the boiling point of spirituous liquids varies according to the amount of alcohol contained in them (a discovery made by the Abbé Brossard-Vidal, of Toulon), without its being essentially modified, like the other instruments, by the presence and nature of any solid ingredients which may be contained in them.

There are several forms of this instrument; there is the original one of M. Brossard-Vidal, and the modifications by M. Conaty, by MM. Lerebours and Secretan, and by Dr. Ure.

The mercurial thermometer used in the modification of the instrument by MM. Lerebours and Secretan is graduated centesimally in degrees, which correspond to those of the centesimal alcoholometer of M. Gay-Lussac, and its bulb is plunged in the liquid to be proved. The liquid is carefully heated by means of a spirit lamp, the flame of which should not be strong, lest it occasion the too rapid ebullition of the spirit. Before using the instrument, it is necessary to determine the boiling point of pure water, and the barometrical pressure of the atmosphere on the day on which the experiments are made.

In Dr. Ure's modification of the instrument, the scale is adapted to that of Sykes' hydrometer.

It would be of the greatest possible advantage—would save much time and trouble—if densimeters of all kinds were revised, and were reduced to one uniform centesimal scale, as is done, in fact, in many of the instruments in use on the Continent.

The ebullioscope is probably sufficiently accurate in the results which it furnishes to afford considerable service to the distiller, the rectifier, the wine-maker, and the brewer; but it is certainly not so where extreme accuracy is required.

Alcoholometric dilatometer.—Another instrument which has been invented for the determination of the proportion of alcohol in spirituous liquids is the *alcoholometric dilatometer* of M. Silbermann. By this instrument, the amount of spirit is determined by the dilation of the spirituous liquid at various temperatures.

Another instrument has been devised by M. Geissler, of Bonn, based upon the expanding power of the steam obtained by heating a spirituous liquid. This power is measured by the height of a column of mercury, which can be raised by the steam at a heat of 100° C. The instrument is called a *vaporimeter*.

Specific Gravity Bottle.—But the most accurate method of determining the quantity of alcohol contained in spirituous liquids from their specific gravity is by means of *the specific gravity bottle*. In using this, the same precautions with regard to temperature and the presence of any solid substance in the spirit must be observed as in the employment of some of the other instruments above referred to.

For ordinary purposes, in the hands of manufacturers and dealers, of all the instruments for determining the strength of spirituous liquors, the centesimal alcoholometer of M. Gay-Lussac is the safest and best, and, next to that, Sykes' hydrometer. But the chemist, when any solid matter is contained in the liquid to be examined, should, in all cases, separate the alcohol by *distillation* and determine its amount from the specific gravity of the distilled liquid, and this is the method by which we have proceeded in the determination of the alcohol contained in the samples of spirits the results of the analyses of which we shall shortly make known. The exact steps to be adopted are as follows:—

Alcoholometrical Table of Tralles.

Alcohol in 100 Measures of Spirit.	Specific Gravity at 60° Fahr.	Difference of the Spec. Grav.	Alcohol in 100 Measures of Spirit.	Specific Gravity at 60° Fahr.	Difference of the Spec. Grav.
0	9991	—	36	9570	13
1	9976	15	37	9556	14
2	9961	15	38	9541	15
3	9947	14	39	9526	15
4	9933	14	40	9510	16
5	9919	14	41	9494	16
6	9906	13	42	9478	16
7	9893	13	43	9461	17
8	9881	12	44	9444	17
9	9869	12	45	9427	17
10	9857	12	46	9409	18
11	9845	12	47	9391	18
12	9834	11	48	9373	18
13	9823	11	49	9354	19
14	9812	11	50	9335	19
15	9802	10	51	9315	20
16	9791	11	52	9295	20
17	9781	10	53	9275	20
18	9771	10	54	9254	21
19	9761	10	55	9234	20
20	9751	10	56	9213	21
21	9741	10	57	9192	21
22	9731	10	58	9170	22
23	9720	11	59	9148	22
24	9710	10	60	9126	22
25	9700	10	61	9104	22
26	9689	11	62	9082	22
27	9679	10	63	9059	23
28	9668	11	64	9036	23
29	9657	11	65	9013	23
30	9646	11	66	8989	24
31	9634	12	67	8965	24
32	9622	12	68	8941	24
33	9609	13	69	8917	24
34	9596	13	70	8892	25
35	9583	13	71	8867	25

Alcoholometrical Table of Tralles.

Alcohol in 100 Measures of Spirit.	Specific Gravity at 60° Fahr.	Difference of the Spec. Grav.	Alcohol in 100 Measures of Spirit.	Specific Gravity at 60° Fahr.	Difference of the Spec. Grav.
72	8842	25	87	8428	30
73	8817	25	88	8397	31
74	8791	26	89	8365	32
75	8765	26	90	8332	33
76	8739	26	91	8299	33
77	8712	27	92	8265	34
78	8685	27	93	8230	35
79	8658	27	94	8194	36
80	8631	27	95	8157	37
81	8603	28	96	8118	39
82	8575	28	97	8077	41
83	8547	28	98	8034	43
84	8518	29	99	7988	46
85	8488	30	100	7939	49
86	8458	30			

100 cc. of the spirit are distilled, and the distillation carried nearly to dryness; the distillate is made up with distilled water to the original bulk, again brought to a temperature of 15·5° C. and its specific gravity ascertained. These particulars being determined, the percentage of alcohol is ascertained by the alcoholometrical table of Tralles, p. 801.

The third column of this table exhibits the difference of the specific gravities which give the denominator of the fraction for such densities as are not found sufficiently near in the table, and the difference of their numerators is the next greatest to the density found in the table; for example, if the specific gravity of the liquor found for 15·5° C. be 9605 (the percentage will be between 33 and 34), the difference from 9609 (which is the next greatest number in the table) = 4, and the fraction is $\frac{4}{13}$, therefore the true percentage is 33 $\frac{4}{13}$, or, decimally, thus, 33·31. In order to ascertain the amount, by volume, of alcohol in the gin or other spirit under examination, it is necessary to proceed as follows:—In order to find the percentage of absolute alcohol of 7939 specific gravity in a sample of spirit, the specific gravity of the spirit is looked for in the second column of the table, and if the exact figure be not found the next higher gravity is taken. For instance, we have obtained a distillate having a specific gravity of 9436, then we find in the table that the next higher specific gravity of 9444 corresponds to 44 per cent. of alcohol. The difference between the two specific gravities is then calculated—in this case it is 8. In the third column we find that a difference of 17 corresponds to one per cent. of alcohol, a difference of 8 therefore to 0·47 per cent., which has to be added to the whole number found. A spirit of a specific gravity of 9436 contains consequently 44·47 per cent. by measure of absolute alcohol.

But now supposing we have subjected 150 cc. to distillation, and have obtained 100 cc. of distillate, which we found to contain 44·47 per cent. of alcohol, we have to consider that this percentage was obtained from 150 cc. We say, therefore, $150 : 44{\cdot}47 = 100 : x$, and by calculating this simple rule of three sum, we find x to be 29·6 per cent.

Detection of fusel oil.—There are no chemical reactions unfortunately whereby the presence of this oil in the minute quantity in which it is ordinarily contained in the wines and spirits of commerce may be detected, much less estimated. The method usually relied upon is the odour of the oil. This is best perceived when the ethylic alcohol has either been allowed to evaporate or when it has been separated by certain special means. A very simple and common practice is to rub some of the spirit between the hands and, after allowing the alcohol to evaporate, the odour may sometimes be perceived.

Or a portion of the spirit may be put into a glass or bottle with some porous chloride of calcium, when the odour of the fusel oil will become, after the lapse of some hours, very perceptible. See p. 796 for further details.

BRANDY AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any foreign spirit, sugar, any acrid or carminative substance, or any substances employed to produce flavour and aroma not derived from the grape. Water in such proportion as to reduce the percentage of absolute alcohol below 50 per cent. by volume.

Brandy is obtained by the distillation of both white and pale red wines, from refuse wines; also from the murk left in the wine press, and the refuse of wine casks. One of the largest brandy-producing countries is the south of France. The quality and strength of brandy depend upon that of the wine from which it is prepared; and as a rule white wines furnish the best brandy, since they contain more of the volatile constituents, especially œnanthic ether, than the red.

The grapes grown in some districts furnish brandy possessed of peculiar aromas; thus the wines of Selleuil, in Dauphiné, furnish a brandy having the aroma of the *Florentine iris*, while those of St. Pierre, in Vivarais, a spirit having the odour of the *violet*.

Of the many descriptions and qualities of brandy, the best is true *cognac*, which is obtained by the distillation of wines of a superior quality. Brandies prepared from inferior wines contain a smaller quantity of the essential oils, and hence they have less of the characteristic bouquet and flavour which distinguish brandies of the first quality.

But owing to the perfection of the machinery now employed in the distillation of spirituous liquids, a superior product is obtained from many inferior descriptions of wine.

A brandy of a lower quality is obtained in Spain and Portugal from the dark red wines of those countries.

In France the brandy sold is usually of two strengths—the one contains from 18 to 20 degrees Baumé, and is called 'eau de vie à preuve de Hollande,' and the other 'eau de vie à preuve d'huile;' but the brandies as first made are stronger than the 'preuve de Hollande,' and are distinguished as five-six, four-five, three-four, two-three, three-five, four-seven, five-nine, six-eleven, three-six, three-seven, three-eight, and three-nine.

The brandies of different districts are stated to be all distinguishable by an experienced dealer by peculiarities in their aroma and flavour.

Genuine French brandy commonly exhibits an acid reaction, owing to the formation of a minute quantity of *acetic acid,* when it is apt also to contain *acetic ether*. Of course when kept in casks for a long time it may take up therefrom both *astringent* and *colouring* matters. When first distilled brandy is perfectly colourless, pale brandy obtaining the colour which it exhibits from the cask in which it is kept, while brown brandy is coloured with sugar or caramel, dissolved in lime water.

Ure says that brandy is sold usually about 10 per cent. under proof, equal to 50·85 per cent. of alcohol by volume.

THE ADULTERATIONS OF BRANDY.

One of the most frequent adulterations of brandy is with *water*.

Another adulteration is with *spirit* obtained from *corn, sugar, molasses, beetroot,* or *potatoes*.

In some cases one or other of these different spirits is substituted for genuine brandy, the flavour of brandy being communicated to them by artificial flavourings, but the requisite colour being obtained by means of burnt sugar.

Much of even the French brandy imported into this country consists either in part or wholly of corn, but more frequently of beetroot spirit.

Strange to relate, a very large quantity of corn spirit has of late been imported into France, to be used in the adulteration of French brandy. Part of this corn spirit is returned to us in the form of brandy, this adulterated brandy on its arrival in this country undergoing in many instances further adulteration by the addition of more corn spirit, and thus it becomes doubly adulterated.

The article known as *British brandy* consists for the most part of corn spirit flavoured. The flavouring is accomplished sometimes by the addition of a little genuine brandy, but more frequently by distillation of the murk, the name given to the refuse skins and pips of the grape left after the distillation of the wine. 'The British brandy maker buys up this murk, and imports it into this country, paying upon it the same duty as upon wine. By distilling British molasses over these lees, the manufacturer obtains, to some extent, the peculiar flavour which characterises French brandy.'—*Tricks of Trade.*

The late Dr. Normandy, in reply to a question put to him by Mr. Scholefield, Chairman of the Parliamentary Committee relative to the Adulteration of Food of 1855, made these remarks in regard to the flavouring of brandy by means of artificially-prepared essences:—'Brandy is extensively prepared in this country, especially since the discoveries of modern chemistry of producing essential oils artificially —oils which have the odour of that particular ether to which brandy owes its flavour.'

When molasses spirit is employed it is necessary it should be previously rectified by distillation over freshly-burnt charcoal and quicklime. Indeed it is essential that all spirits, especially potato spirit, employed in the adulteration of brandy should undergo careful rectification, in order to free them from the peculiar tastes and odours, which might but too plainly reveal the nature and origin of the spirit.

Receipts are of course not wanting for the manufacture of spurious French brandy. Dr. Ure gives the following formula as one which is employed for converting *corn spirit* into imitation brandy. Pure alcohol is to be diluted to the proof strength; to every hundredweight of the spirit, half a pound of *argol, wine-stone, or cream of tartar* previously dissolved in water, is added, as well as a little *acetic ether*, some French *wine vinegar*, bruised *French plums*, and *flower stuff* from Cognac (murk). The spirit is then to be distilled off, with a gentle fire, in an alembic furnished with an agitator. The spirit which comes over is coloured with burnt sugar to the tint required, and roughened to the taste with a few drops of the tincture of *catechu* or *kino.*

Oak sawdust and tincture of grape stones, prepared purposely from the murk, are used to impart to new brandy the taste of an old spirit which has become ripened in an oaken cask.

The author of a work on 'Malted and Unmalted Corn, connected with Brewing and Distilling,' gives the following receipt for making an adulterated brandy, suitable for retail purposes:—

To 10 puncheons of brandy	1,081	gallons
Add flavouring raisin spirit . . .	118	”
Tincture of grains of paradise . .	4	”
Cherry laurel water	2	”
Spirit of almond cake	2	”
Total . .	1,207	gallons.

Add also, 10 handfuls of oak sawdust, and give it complexion with burnt sugar.

The case of brandy affords, then, an apt illustration of the pitch of refinement to which the art of adulteration has reached in these days.

Results of the Examination of Samples.

Of *eighteen* samples of brandy subjected to examination—

The *alcohol* ranged from 30 to 50 per cent. by volume.

The majority of the samples consisted of so-called *British brandy.*

Nearly all the brandies were coloured with *burnt sugar.*

Lastly, in none of the samples was *Cayenne* present. This is particularly worthy of note, because some of the brandies were procured at houses at which both the gin and rum were found to be adulterated with that substance. This at least shows that acrid substances are not so frequently employed in the adulteration of brandy as of other spirituous liquors. This result is, therefore, in some degree satisfactory.

Brandy and rum are seizable if sold by or found in the possession of the dealer unless it possesses a certain strength, 17 per cent. below proof, by Sykes' hydrometer, equal to 40 per cent. by weight. The following are the words of the Act 30th Geo. III.:—

'No distiller, rectifier, compounder, or dealer shall serve or send out any foreign spirits of a lower strength than that of one in six under hydrometer proof, nor have in his possession any foreign spirits mixed together except shrub, cherry or raspberry brandy, of lower strength than as aforesaid, upon pain of such spirits being forfeited; and such spirits, with the casks and vessels containing the same, may be seized by any officer of Excise.'

It will be perceived that many of the brandies examined by us were sold in violation of the Act above quoted, and, as usual, without let or hindrance by the Excise.

DETECTION OF THE ADULTERATIONS OF BRANDY.

The adulterations of brandy already noticed are with *water, foreign spirit, sugar, burnt sugar,* and various substances to impart flavour and aroma, as *grains of paradise, tincture of catechu or kino,* a tincture prepared from the *seeds of the grape, artificial essence of brandy, raisin spirit, cherry laurel water,* and the water distilled from *almond cake.*

If we except grains of paradise the other substances used are usually present in too minute quantities to be discoverable by the ordinary methods of analysis pursued operating on the quantity of brandy usually submitted to the analyst. We therefore do not propose to dwell upon the methods whereby some of the substances above enumerated might under certain favourable circumstances be detectable, but we limit our observations to water, extraneous spirit, sugar, burnt sugar, and grains of paradise.

Water.—The amount of water present in any spirituous liquor not containing any considerable quantity of solid matter may be approximately determined by simply taking the specific gravity of the liquid and deducing from it by reference to certain tables, which have been specially prepared for the purpose, the amount of absolute alcohol or spirit thereby indicated. But when solid matter is present one portion of the spirit must be distilled and the amount of alcohol in the distillate determined, and another portion must be evaporated on the water-bath, and the solid matter present so ascertained. With these data the quantity of water is then determined by difference.

Extraneous spirit.—The rectification of potato, corn, and other spirits not derived from the grape is in these days usually so perfect that the detection of foreign spirit, that is, spirit not derived from the grape, is impossible in many cases. When, however, the spirit is less perfectly rectified and contains minute quantities of fusel oil, it may be discovered in some instances by the methods already referred to for detecting the disagreeable and characteristic odour of that substance. See pages 796 and 803.

Sugar.—For the determination of sugar, whether grape or cane, we refer the reader to the article on 'Sugar.'

Burnt sugar.—See the report on 'Vinegar.'

Detection of Cayenne pepper and grains of paradise.—The detection of Cayenne and grains of paradise is readily effected in the case of brandy and other spirits by simply evaporating a portion of the spirit and tasting whatever residue be left. The presence of Cayenne is sufficiently demonstrated by the irritating character of the vapours evolved when the substance containing it is burnt. Supposing the fiery and pungent residue not to give off such vapours, this would lead to the inference that the substance to which the pungency was due really consisted of grains of paradise, but since these contain not only a fixed resin of an acrid and burning taste, but also a volatile oil having the smell of camphor and a hot penetrating taste, a further means of discrimination is thereby afforded.

RUM AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any foreign spirit, added sugar, or any acrid or carminative substance, or any substances employed to produce flavour and aroma. Water in such proportion as to reduce the absolute alcohol to below 50 per cent. by volume.

RUM is the spirit obtained from the fermented skimmings of the juice of the sugar cane, mixed with a proportion of molasses and lees, and diluted with water.

'The wort is made in Jamaica by adding to 1,000 gallons of dunder

120 gallons of molasses, 720 gallons of skimmings (= 120 of molasses in sweetness) and 160 gallons of water; so that there may be in the liquid nearly 12 per cent. of solid sugar. Another proportion often used is 100 gallons of molasses, 200 gallons of lees, 300 gallons of skimmings, and 400 of water; the mixture containing, therefore, 15 per cent. of sweets.'—*Ure.*

From 1,200 gallons of the saccharine liquid thus prepared usually about 115 gallons of rum of the strength of proof spirit are obtained.

In France a large quantity of spirit is made from the molasses of the beetroot sugar manufacture.

It sometimes happens, in consequence of the large quantities of lime and potash contained in the liquor, which impart to it an alkaline reaction, that the fermentation is stopped and cannot be then revived until the alkali has been neutralised by the addition of sulphuric acid.

Rum owes its distinctive smell and taste to a peculiar volatile ether, *butyric ether* or *butyrate of ethyl.*

It differs from other spirits in its tendency to cause perspiration; for this reason it is often used by those suffering from colds and coughs.

THE ADULTERATIONS OF RUM.

The adulterations of rum consist chiefly in the addition of *water,* whereby its strength is reduced; of *Cayenne* or *cocculus indicus,* to give the adulterated article apparent strength; and, lastly, of *sugar* and *burnt sugar,* to restore the sweetness and colour lost in consequence of dilution.

An instance leading to fatal results of the adulteration of rum with *cocculus indicus* occurred some years since at Liverpool. It is recorded in Dr. Taylor's book on 'Toxicology.'

Several sailors drank a glass each of the sophisticated spirit; one died the same evening, but the others, although made seriously ill, ultimately recovered.

Lead has been discovered in rum in some cases; this is generally to be regarded as an accidental impregnation, the lead being derived from the worm of the still. It is in *new* rum that lead is chiefly met with. Dr. Traill found that the spirit received into a tumbler as it came from the still always contained lead, but that it disappeared from the same spirit after having been kept in an oaken cask for some time. The explanation of this curious fact is, that the spirit extracts tannin from the cask, and the lead uniting with this forms an insoluble compound and becomes precipitated.

There is a kind of rum termed 'Pineapple Rum.' The flavour of pineapple is communicated to the spirit by steeping in it slices of the pine. Recently chemists have found out methods of imitating very exactly the flavour of the pine, and hence this artificially prepared flavouring is often had recourse to in this country to convert not only ordinary rum, but even ordinary spirit into 'Pineapple Rum.'

This flavouring may be prepared by distilling butter with sulphuric acid and alcohol, or by combining amylic or potato alcohol with butyric acid, and then dissolving the butyrate of amyl formed in alcohol. This flavouring is much used in sweetmeats.

Results of the Examination of Samples.

Of *twenty* samples of rum subjected to analysis, the *alcohol* ranged from 47 per cent. by volume the highest, to 27 per cent. the lowest, while *Cayenne* was detected in six of the samples; that is, some of the spirits did not contain much more than *half* as much alcohol as others, and consequently were of little more than *half* the value. The same was found, as will appear hereafter, to be the case with the gins examined; some of them contained only half the quantity of spirit that others did, and this although the price paid for them was nearly the same in all cases.

THE DETECTION OF THE ADULTERATIONS OF RUM.

The methods to be employed for the detection of *water, sugar,* and *Cayenne* are the same as those referred to under the head of 'Brandy.'

The processes for the detection of *grains of paradise* and *cocculus indicus* will be found described in the article on 'Beer.' It is easier to discover the presence of the latter in rum than in beer, owing to the smaller quantity of extractive matter contained in that spirit. A very excellent method of determining the presence of cocculus indicus is to evaporate about half a pint of rum to dryness, to dissolve the extract in about ten ounces or so of water, and to place in it a small live fish. If the spirit contain picrotoxin the fish will soon exhibit the usual symptoms of poisoning by that deadly substance.

For the process for the detection and estimation of the *lead* see reports on 'Water' and 'Vinegar.'

GIN AND ITS ADULTERATIONS.

DEFINITION OF ADULTERATION.

Any acrid substance, sulphuric acid, combined or free, lead, zinc, and water in such proportion as to reduce the absolute alcohol to below 50 per cent. by volume.

GIN was made originally in Holland, in the distilleries of Schiedam, and hence that which is brought to this country is termed 'Hollands gin.'

In Holland it is made solely from unmalted rye and barley malt, rectified with juniper berries. In Britain, gin is for the most part obtained from a mixture of malt and barley, molasses and corn being sometimes employed, particularly when there is a scarcity of grain; and it is usually flavoured not only with juniper berries, but with certain other substances, most of which are aromatics, and amongst which are the following: *coriander*, *cardamom*, and *caraway seeds*, *grains of paradise*, *angelica root*, *calamus root*, crushed *almond cake*, *liquorice powder*, and *orange peel*. These ingredients, variously combined, form what is known in the trade as 'gin flavouring.'

Pure gin should consist, as does Hollands, solely of rectified corn spirit flavoured with juniper berries.

THE ADULTERATIONS OF GIN.

Gin is commonly diluted or adulterated with large quantities of *water*.

But since the addition of water to gin renders the mixture whitish and turbid, by occasioning the precipitation of the oily and resinous matters of the juniper and other substances employed to flavour the gin previously held in solution by the spirit, it becomes necessary to 'fine' the gin, as it is termed, that is, to restore the transparency of the spirituous mixture.

The substances more commonly employed for this purpose are *alum*, *carbonate of potash*, and occasionally *acetate of lead*. Alum dissolved in water is first added to the weakened spirit, and then a solution of carbonate of potash. The whole is stirred together, and left at rest for twenty-four hours. The alumina of the alum, precipitated by the carbonate of potash, acts 'as a strainer upon the milky liquor, and carries down with it the finely-divided oily matter, which produces the blue colour of the diluted liquor.'—*Accum.*

Roche alum is sometimes used for clarifying spirituous liquors without any other addition.

'Another method consists in adding first a solution of subacetate of lead, and then a solution of alum. This practice is highly dangerous, because part of the sulphate of lead produced remains dissolved in the liquor, which it thus renders poisonous. Unfortunately this method of clarifying spirituous liquors, I have good reason to believe, is more frequently practised than the preceding method, because its action is more rapid, and it imparts to the liquor a fine *complexion*, or great refractive power; hence some vestiges of lead may often be detected in malt spirit.'—*Accum.*

Another substance added to gin is *sulphuric acid*. Mr. Mitchell states that a mixture composed of alum, carbonate of potash, almond oil, sulphuric acid, and spirits of wine, is frequently added to gin. 'This compound,' he remarks, 'not only fines the gin, but communicates to it the property of "beading," or hanging in pearly drops or beads on the sides of the glass containing it. When gin does this, it is generally supposed to be strong in proportion as it beads, and the above mixture communicates to weak gin that property, so that it will be evident gin can be considerably diluted with water, and yet, by the addition of the above, appear of its proper strength.'

But opacity is not the only evil produced by the addition of water to gin; the strength and flavour of the gin are so reduced that it becomes necessary to add other substances to restore the qualities lost by dilution—these being *sugar* to sweeten it, and *cayenne,* in the form of *tincture of capsicum,* or *grains of paradise,* to give it pungency and apparent strength.

The flavour and properties of gin are further modified by the use of compounds known as *gin flavourings.*

These are composed of various cordial and aromatic substances, each distiller usually giving the preference to a formula of his own.

In Dr. Muspratt's 'Chemistry' will be found several receipts for gin flavourings, copied from the note-book of an extensive spirit rectifier. Two of these are as follows:—

Plain or *London Gin* is made as follows:
700 gallons of the second rectification.
70 lbs. German juniper berries.
50 lbs. coriander seeds.
3½ lbs. almond cake.
1½ lb. angelica root.
6 lbs. liquorice powder.

For the manufacture of *West Country Gin,* known also as Plymouth gin, the annexed is the process given in Dr. Muspratt's work:—Introduce into the still 700 gallons of the second rectification, and flavour with—

14 lbs. German juniper berries.
1½ lb. calamus root, cut; and
8 lbs. sulphuric acid.

This gin is much used in Cornwall, and particularly in the western counties of England; it is also used in making British Hollands, and in that case is mixed with about five per cent. of fine gin, reduced to twenty-two under proof with liquor.

Amongst the ingredients enumerated in the other receipts, and not contained in those above given, are orange peel, calamus root, cassia buds, orris root, cardamoms, and grains of paradise.

In Shannon's work, 'On Brewing and Distilling,' we meet with the following instructions for reducing unsweetened gin, and for preparing and sweetening British gin:—

To Reduce Unsweetened Gin.

A tun of fine gin	252	gallons.
Water	36	”
Which, added together, make . . .	288	”
The *Doctor is now put on,* and it is further reduced with water	19	”
Which gives	307	gallons of gin.

'This done, let one pound of alum be just covered with water, and dissolved by boiling; rummage the whole well together, and pour in the alum, and the whole will be fine in a few hours.

'*To Prepare and Sweeten British Gin.*

'Get from your distiller an empty puncheon or cask, which will contain about 133 gallons. Then take a cask of clear rectified spirits—120 gallons—of the usual strength at which rectifiers sell their goods; put the 120 gallons of spirits into your empty cask.

'Then take a quarter of an ounce of oil of vitriol, half an ounce of oil of almonds, a quarter of an ounce of oil of turpentine, one ounce of oil of juniper berries, half a pint of spirit of wine, and half a pound of lump sugar. Beat or rub the above in a mortar. When well rubbed together, have ready prepared half a gallon of lime water, one gallon of rose water: mix the whole in either a pail or cask, with a stick, till every particle shall be dissolved; then add to the foregoing twenty-five pounds of sugar dissolved in about nine gallons of rain or Thames water, or water that has been boiled: mix the whole well together, and stir them carefully with a stick in the 133-gallon cask.

'To *force down* the same, take and boil eight ounces of alum in three quarts of water for three-quarters of an hour; take it from the fire, and dissolve by degrees six or seven ounces of salt of tartar. When the same is milkwarm, pour it into your gin, and stir it well together as before, for five minutes, the same as you would a butt of beer newly fined. Let your cask stand as you mean to draw it. At every time you propose to sweeten again, that cask must be well washed out, and take great care never to shake your cask while it is drawing.'

But it appears there are other little practices, besides those connected with adulteration, which are sometimes had recourse to by retailers of spirits. Mr. Shannon, from whose work 'On Brewing and Distilling' we have just quoted, gives the following advice and recommendations as to certain manipulations and particulars which should be observed in retailing spirits over the counter.

'When you are to draw a sample of goods to show a person that has judgment in the proof, do not draw your goods into a phial to be tasted, or make experiment of the strength thereof that way, because the proof will not hold except the goods be exceedingly strong; but draw the pattern of goods either into the glass from the cock, to run very small, or rather draw off a small quantity into a little pewter pot, and pour it into your glass, extending your pot as high above the glass as you can without wasting it, which makes the goods carry a better head abundantly than if the same goods were to be put and tried in a phial.

'You must be so prudent as to make a distinction of the persons you have to deal with; what goods you sell to gentlemen for their own use who require a great deal of attendance, and as much for time of payment, you must take a considerably greater price than of others; what goods you sell to persons where you believe there is a manifest, or at least some, hazard of your money, you may safely sell for more than common profit; what goods you sell to the poor, especially medicinally (as many of your goods are sanative), be as compassionate as the cases require.'

Results of the Analysis of Samples.

The following are the results of the analysis of *Thirty-eight* samples of gin:—

That the *strength* of the various samples ranged from 15,645 grs. to 34,160 grs. per imperial gallon; the percentages ranging from 22·35 to 48·80 per cent. by volume.

It thus appears, that some of the spirits contained less than half as much alcohol as some of the other samples, and therefore that their commercial value was reduced to the enormous extent of more than one-half; thus, supposing the stronger sample to be worth 12*s.* per gallon, the weaker would be worth less than 6*s.* per gallon. This variation in the strength is doubtless principally attributable to dilution with water.

That the quantity of *sugar* ranged from 2·43 per cent. to 9·28 per cent.

That *two* of the samples contained *oil of cinnamon*, or more probably of *cassia.*

That *seven* of the samples contained CAYENNE PEPPER, some of them in very large quantity, so that the syrupy extract left on evaporation possessed a burning and fiery taste.

That in no case was *free sulphuric acid* detected; its absence being sufficiently shown by all the samples being neutral to test paper.

That *most* of the samples contained sulphates, chiefly derived from the water and alum used in the adulteration and clarification of the gins.

In addition to the above adulterations, we have the authority of a gin distiller for stating that the practice of adding *sulphate of zinc*, or as it is commonly called, *white vitriol* or *white copperas*, to gin is very common. Here again, then, we have obtained evidence of the adulteration of gin in a manner calculated to prove injurious to health.

It is impossible to conceive of more scandalous adulterations of gin or other spirits than those by *Cayenne pepper* or *grains of paradise*, for they are almost equally hot and pungent. The introduction into the stomach of raw spirits is sufficiently destructive to health of itself, but the addition to the spirit of such powerful and acrid substances as Cayenne and grains of paradise forms a compound which no human stomach or system, however strong, can long withstand.

Although *sulphuric acid* was not present in any of the samples of

London gin which we examined, it is yet, no doubt, sometimes employed, and this in large quantity. Dr. Muspratt states that it is so in West Country gin. If any sample of gin exhibit an acid reaction, the presence of sulphuric acid may be suspected, and it may be discovered simply by the evaporation at a gentle heat of a little of the gin, placed on the hob of a fireplace. As soon as all the spirit and water have been driven off, the sulphuric acid will act on the sugar, and quickly reduce it to a black carbonaceous mass.

The adulteration of gin with Cayenne pepper is mostly effected by means of tincture of capsicum, and it is practised in the majority of cases by publicans. We were acquainted with the name of a publican who used to make periodical purchases of tincture of capsicum; we know the name of the chemist of whom he purchased it, and we detected it in more than one sample of the gin sold by him.

We have often in the course of this work commented on what we conceived to be the remissness of the Excise authorities. Here is a gross adulteration of gin, commonly practised, and detectable in a ready and simple manner, by which the revenue is defrauded, and which is seriously detrimental to health; and yet we do not remember to have ever heard that the Excise had noticed it in any way, or taken any steps to put a stop to so iniquitous an adulteration.

DETECTION OF THE ADULTERATIONS OF GIN.

The principal adulterations, as already noticed, to which gin is liable are with *water*; *Cayenne*, and *grains of paradise* to render it fiery and pungent; with various flavouring substances, including *almond cake*; *sulphuric acid* to give it sharpness on the palate; and certain mineral constituents employed for the purpose of clarification, as *sulphate of alumina and potash* or *alum*, *carbonate of potash*, *acetate of lead*, and *sulphate of zinc*.

Estimation of water.—Since the gin met with in commerce is of two kinds, sweetened and unsweetened, in the one case it will be necessary only to take the specific gravity of the spirit and to determine from it the amount of absolute alcohol by weight per cent.; the remainder of the hundred parts will consist of water. But in the case of the sweetened gin it will be requisite to subject it to distillation, to estimate the alcohol in the distillate, and to weigh the solid matter left after complete evaporation on the water-bath. By the first proceeding we ascertain the number of alcohol percentages by weight in the gin, by the second the amount of solids, the water making up the difference.

Estimation of alcohol.—For the methods whereby this is determined, the reader is referred to the articles on 'Wine,' 'Beer,' and 'Brandy,' but it will be sufficient in the case of gin to refer to the last-named only.

Detection of Cayenne pepper and grains of paradise.—See the articles on 'Beer' and 'Brandy.'

Estimation of sugar.—The solid residue left on the evaporation of a given quantity of gin, will represent within a fraction the amount of cane sugar which has been added to the spirit.

Detection of certain Carminatives and Flavouring Substances.

For the detection of these two methods may be pursued. The one is to subject a portion of the spirit to distillation and to notice particularly and carefully the odour of the distillate.

Another method is to evaporate a second portion of the spirit on the water-bath at a very gentle heat, and to carefully taste the residue left, as soon as it acquires the consistency of a thin syrup. One of the substances which will readily be detected in this manner is *ginger*.

Detection of Cherry Laurel Water or Spirit of Almond Cake.

Distil the spirit nearly to dryness, add to the distilled liquid a little caustic potash, evaporate down to a small bulk; add a few drops of a solution containing ferrous sulphate and ferric chloride, render alkaline with a solution of potash; now add a little hydrochloric acid, and if the liquid acquires a blue tinge, the spirit under examination has been flavoured with cherry laurel water or spirit of almond cake.

The reactions are as follow:—The *hydrocyanic or prussic acid* of the laurel water and almond cake, when the spirit is distilled, passes over, and on the addition of the potash is converted into cyanide of potassium; the addition of the salts of iron and hydrochloric acid occasions the formation of prussian blue, which is a ferrocyanide of iron.

A more delicate method is the following, first described by Liebig:—The liquid must be distilled as before, potash added, the bulk of the spirit reduced by evaporation; hydrochloric acid must next be added in slight excess, and then a drop of sulphide of ammonium, and the whole heated until colourless. A little perchloride of iron must now be added, when, if prussic acid be present, the liquid will become of a blood-red colour. Sulphocyanide of ammonium is formed by the action of sulphide of ammonium upon hydrocyanic acid, and this, like other soluble sulphocyanides, strikes a blood-red colour with a persalt of iron.

A little of the volatile almond oil or hydride of benzoin will of course pass over as well as the hydrocyanic acid by the distillation of the spirit.

We come now to treat of the mineral adulterations of gin, including those with free sulphuric acid and sulphates, alum, salts of lead and zinc.

Estimation of combined and free sulphuric acid.—For the determination of these refer to the articles on 'Water' and 'Vinegar.'

The addition of chloride of barium to gin which has not been adulterated with water, should not occasion any precipitation of sulphate of barium if the water contained in the spirit is all obtained by distillation. When therefore, on the addition of the above reagent, a precipitate be thrown down, this is due either to the presence of free or combined sulphuric acid; if the latter, and there be no sulphate of zinc present, the sulphates are derived either from the water used for the dilution of the spirit or from the alum employed for clarifying and beading it, so that the presence of sulphates affords in most cases a certain indication of the adulteration of gin with water. Although it must be remembered that possibly the sulphuric acid of the sulphate of barium thrown down might be derived from the acid of the alum.

Of ten samples of gin to which the solution of chloride of barium was added, four turned slightly opalescent, but scarcely any deposition of sulphate occurred; while in six of the samples there was a decided, and in three a considerable, precipitation. These gins were likewise evaporated, the residues dissolved in a little distilled water, and the solution divided into two parts; to one the acid solution of chloride of barium was added as before, when sulphate of barium was thrown down in every case, and in most in great abundance. The other half of the solution was tested for zinc. In no instance was any precipitate observed, from which the absence of zinc is to be inferred. These observations as to the presence of sulphates in gin are important, because they afford in many cases the means of judging of the adulteration of gin by the addition of water. Heretofore the presence of added water has been inferred rather than proved, from the deficiency of alcohol in the spirit supposed to contain the water. But, again, it must be remembered that waters are met with which are almost entirely free from combined sulphuric acid.

There is only one other source of fallacy with which it is necessary that we should be acquainted. Supposing sulphuric acid to have been added to the gin, a precipitation would equally occur, although no water had been added, on the addition of chloride of barium. This fallacy may be guarded against by ascertaining in the first place whether the gin exhibits an acid reaction or not to test paper, and if it does, we must then proceed as directed for the determination of free and combined sulphuric acid.

The detection of alum in gin.—Add to 50 cc. of the gin a few cc. of a solution of chloride of ammonium, and render the mixture distinctly alkaline with ammonia. If a white precipitate be thrown down, which, after being washed with distilled water, is soluble in caustic potash, alum is proved to be present. The precipitate may be collected, dried, burnt and weighed, and calculated for alum.

But since alum is often used in conjunction with carbonate of potash, the alumina will not be usually found in the spirit, since, for the most part, it will be precipitated by the alkali used, and which itself will be converted into sulphate of potash.

Detection of lead.—The full details of the methods for the detection of lead have already been given in the article on 'Vinegar.'

Ten different samples of gin were examined for lead, but only in one case did sulphuretted hydrogen produce a decided brownish coloration; in some of the others slighter colorations were observed, but in none of the gins was lead discovered in the ashes treated with nitric acid and water. If lead was therefore present in any of the samples it was so only in traces.

The absence of lead may be explained in some cases even where it has really been used in the following manner. The lead of the acetate would combine with the sulphates of the water, and the insoluble sulphate of lead would be precipitated; it is, therefore, only when the quantity of lead added is in excess of the sulphates, that it would be found in gin, and when sulphates are present in gin we may conclude that it does not contain more than traces of lead.

Detection of sulphate of zinc in gin.—Evaporate 100 cc. of the gin to at least one half, so as to get rid of the alcohol; restore to the original volume by the addition of water, and divide into two portions, testing the one for sulphuric acid and the other for zinc, after neutralisation with ammonia, by the addition of sulphide of ammonium.

We will now enquire as to the capabilities of the Excise to detect adulterations in spirits; and first the reader may be reminded that adulteration has been found to be rife in brandy, rum, and gin. As in so many other cases, we need only refer to the evidence of Mr. George Phillips to be made acquainted with the state of the case as respected the knowledge of the Excise some years since.

Mr. Villiers. 'We have had evidence here to the effect that a mixture or adulteration is invariable in all public-houses: what is the course adopted with a view to detecting those practices?'—'The fact is, we have abandoned what is termed stock-taking of the retailers. The trade is thrown open, and they are left to do pretty much as they like. At the present moment, so far as stock-taking is concerned, we have power to take their stock if we think proper; the goods are sent in with a permit, and the trader enters them in a book, and when the officer goes he takes up this document representing the receipt of a certain spirit, and if we think proper we can take the stock.'

'Is not the revenue defrauded in this way?'—'I think not. If the public wished to drink gin at 50 per cent. under proof, the retailer could have it sent to him. *The law prohibits him from putting anything to it himself. He is not allowed to add sugar or water to his gin; it is an act of compounding which we do not recognise.*'

'The duty is not paid on gin and water?'—'No; it is paid on the spirit. Suppose, for instance, the publican buys his gin at 17 under proof. That may be too strong for ordinary taste, and therefore the publican, when he gets it at that strength, reduces it probably. *I* *cannot say that he does so from actual knowledge,* but we may suppose that he does.'

It is notorious that the publican almost constantly reduces his gin with water, adds sugar, and often Cayenne and other ingredients. As has been stated by Mr. Phillips, the law prohibits this act of compounding, and has charged the Excise with the duty of ascertaining whether the prohibition is observed or not; but the Excise leaves the publicans 'to do pretty much as they like,' and consequently they are unable to speak to facts in regard to the adulteration of gin which are notorious to the public at large. But let us observe what further information Mr. Phillips affords the Committee respecting the adulteration of spirits.

Chairman. 'Have you heard of Cayenne pepper being mixed with *gin*?'—'I have *heard* so; it could be detected, of course.'

Mr. Villiers. 'Have you never had any experience of the adulteration of spirits during the twelve years you have spoken of?'—'*I do not recollect a case.*'

'Is brandy ever adulterated?'—'If you view colouring matter as adulteration, it is always adulterated.'

'Do you know if it is ever reduced with water and then made stronger by the introduction of other ingredients?'—'I cannot speak to the use of other ingredients. I have no knowledge of what a particular trader may do.'

'The evidence which has been given before the Committee, therefore, has not reached the Excise yet?'—'I have not seen it.'

These replies certainly evince an amount of ignorance of the adulterations occurring in the articles enumerated, which, considering the position and duties of the Excise, is really astounding.

Preparation of Potato Spirit.

Alcohol is prepared from potatoes on a large scale by two methods. The potatoes are boiled, mashed between cylinders and the thick pulp thus obtained mixed with crushed malt and water, and the mixture subjected to fermentation in the usual manner, or the potatoes are boiled with water containing some sulphuric acid, for some hours until all the starch is converted into dextrin and invert sugar, this solution being then fermented. The fermentation and distillation of the spirit offer no particular interest, these processes being conducted in the same way as in the case of spirit from malt and grain.

A considerable quantity of *fusel oil* is formed, which is removed by one or the other of the methods described elsewhere, and the spirit so obtained resembles closely the alcoholic liquid denominated 'Hollands.'

CHAPTER XLVII.

ON THE UTENSILS EMPLOYED IN THE PREPARATION AND STORAGE OF FOOD.

Many articles of food are very apt to become more or less contaminated with various metallic substances through the vessels employed, either to cook, store, or convey them from one vessel to another. Many instances have already been given of contamination arising through contact with vessels either consisting entirely of metal, or into the composition of which metallic substances enter; but on the present occasion we propose to deal with this subject more comprehensively and by itself. It is very important that the analyst should have as thorough a knowledge of the contaminations to which articles of food are liable as of the adulterations to which they are subject, lest he confound the one with the other, and charge a manufacturer with adulteration when the case is one of careless and accidental impregnation only. Now the action of articles of food upon metals is dependent upon several circumstances, and especially upon the composition of the food itself. For food to become contaminated with a metal derived from the vessel in which it is cooked, it is not sufficient that the metal and the food be brought into contact, but such agencies must be in operation as cause a solution of a portion of the metal. The first of these is oxygen, which, since it is a constituent of the atmosphere, and is always contained in water, is everywhere present. By this agent oxides of the metals are formed. The second consists in the free acids of the food; these do not act usually upon the metals themselves, but upon the oxides already referred to, forming with them various salts of greater or less solubility. A third agency is found in the substances added by the cook to various articles of food, including *acetic acid* or *vinegar*, *chloride of sodium* or *salt*, and *alkalies* as *soda*. The action of acetic acid has already been explained, that of the chloride of sodium would appear to be due to the liberation of a portion of its chlorine, while the action of the alkalies is thus accounted for. Oxide of lead in some cases plays the part of an acid, forming with bases plumbates; thus if soda be used a plumbate of soda is formed.

It would appear, therefore, that meats which have been salted are more liable than other meats to act upon any soluble metal which might be in the utensil in which it is cooked—as, for example, solder.

Other substances which are capable of exerting a solvent action upon many metals are *fats* and *sulphur*. The action of fats upon metals is thus explained. The oxides of some metals, as of copper and lead, readily decompose a portion of the fat, glycerine being set free, and combinations of the fatty acids with the metals ensuing.

Sulphur exists in meat and in many kinds of vegetables, as onions, partly in the form of sulphides. These readily become decomposed, uniting with any metal with which they come into contact.

In *preserving* many substances, as in making various descriptions of jams, as is commonly done, in copper vessels the fruits are exceedingly apt to become contaminated; this contamination is due in part to the oxidation of the metal and the subsequent formation of the soluble tartrate, acetate, or malate of copper, as the case may be; but it is also in part due to the peculiar action of the *sugar*, this forming with several metallic oxides so-called *saccharides*. The oxygen of the oxides takes away part of the hydrogen of the sugar to form water, the metal taking the place of the hydrogen.

Since it is necessary that the copper and other metals should become oxidised before the formation of any soluble salt can take place, we have in this circumstance the strongest possible reason why the fruit or other substance prepared in copper or other metallic vessels should not be allowed to remain in contact with them a moment longer than is absolutely necessary, and why these vessels should be always kept as bright and clean as possible. Should the vegetable substances be allowed to remain in a copper pan for any length of time, the greatest action will be found to take place at the margin, where the air, fruit, and copper all come into contact. Here will be the greatest formation of oxide, and consequently of soluble salts of that metal, which, if the fruit be allowed to remain in the vessel for a sufficiently long time, will reveal themselves by their green colour, forming what is popularly known as *verdigris*, but which, in the present case, consists chiefly of tartrate and malate of copper.

For *cooking*, saucepans are made of iron, copper, brass, and tin, and hence, when articles of food are cooked in these utensils, they are very apt to become contaminated with the metals of which they are composed, especially when they are not coated in the inside with tin. Now *tin*, when pure, is one of the least objectionable of the metals used in the manufacture of cooking utensils, and this for two reasons: first, it combines with oxygen or oxidises with greater difficulty than most of the other metals; and, second, the salts formed with it are of a much less injurious character than are those of copper, lead, zinc, and arsenic.

But much of the tin employed, especially that used for coating vessels, is not pure, but contains contaminations of other metals, as arsenic, antimony, lead and copper. Now these metals are all readily oxidised and dissolved by the various acids either directly added to the food in the saucepan, or contained in the ingredients entering into its composition, as the lactic acid in meat and milk, and the various acids of fruit. Hence, while the tin lining of vessels, so long as the coating is complete, precludes the action of the articles contained in it upon the more soluble and injurious metals, it is yet attended with certain dangers of its own, but which no doubt are far less considerable than those arising from the use of uncoated metallic vessels. On the whole, therefore, it may be said that tin vessels, or those lined with tin, are the best of all metal vessels employed for cooking purposes.

So common is the practice of making vessels of *copper* that, when of large size, they are commonly distinguished by the name of 'coppers.' The water used to cleanse our clothes is boiled in such vessels, and the wort of brewers is always boiled in utensils composed of copper. It is from this source that beer obtains its not unfrequent contamination with copper. Mr. Mitchell has stated that he found copper in a great variety of samples of beer which he examined.

Another way in which articles of consumption frequently become contaminated with copper is by boiling vinegar in copper vessels. This is done for the express purpose of causing the vinegar to dissolve a portion of the copper, so that the metal, when the vinegar is brought into contact with the pickles to be preserved, should impart to them an unnaturally green colour.

The green colour of greengage and gooseberry jam is usually due to the copper removed from the vessels in which these jams are prepared, through the agency of the acids contained in the fruits; but sometimes the copper is directly added in the form of the sulphate of the metal, commonly known as *blue stone*.

Again, it is known to every housekeeper that a very common practice whereby vegetables, as peas and French beans, are greened, is to put into the saucepan a penny piece; and in this case the copper is abstracted from the coin partly through the agency of the acids of the vegetable, but also in some instances through certain of the saline substances present in the water.

To sum up. M. Thierry, who wrote a thesis on the noxious qualities of copper, observes that 'our food receives its quantity of poison in the kitchen by the use of copper pans and dishes. The brewer mingles poison in our beer by boiling it in copper vessels. The sugar baker employs copper pans, the pastrycook bakes our tarts in copper moulds, the confectioner uses copper vessels, the oilman boils his pickles in copper or brass vessels, and verdigris is plentifully formed by the action of the vinegar upon the metal.'

An *alloy* greatly used in the manufacture of cooking utensils, and in that of vessels intended for storage, as also in the making of pipes and taps, is *brass*, which is compounded of two parts of copper to one of zinc. Thus we have brass saucepans and teakettles, brazen ewers and tubs, and brass pipes and taps innumerable. The two metals entering into the composition of this alloy are both very soluble, their combinations and solutions being of a highly poisonous character.

In place of being lined with tin, many vessels, both metallic and earthenware, are provided with a protective lining or *glaze*. Thus saucepans, kettles, frying-pans, and gridirons are all commonly furnished with such a coating, as also earthenware baking and pie-dishes, pans and jars of various kinds.

The glazing employed is of two kinds. The one consists chiefly of a silicate of alumina and potash with a proportion of sulphate or phosphate of lime, but other substances are also sometimes made use of. It is with this kind that metallic vessels are usually lined. Into the composition of the other lead enters, in the several forms of *galena* or sulphide of lead, *white lead*, *litharge*, and *minium*.

The first kind of glazing is exceedingly insoluble, and it forms undoubtedly the best material which has hitherto been devised with which to line copper and iron vessels. It is to be regretted, however, that it is so brittle and liable to crack, either from heat improperly applied or violence of any kind.

The second kind of glazing is used chiefly in the coating of the interior of baking and pie dishes, pans and jars, and is highly objectionable in consequence of its composition and its greater solubility. It is a common practice to bake meat in such dishes, and here the fatty matter which flows from the joint will be sure to exert a solvent action upon the glaze. It is equally common to store jam and bake fruit in such jars and dishes, the acids strongly acting, of course, upon the glaze.

The efficiency of the lead-glaze depends in a measure upon the baking. It is stated in 'Muspratt's Chemistry' that badly baked ware readily afforded ind cations of the presence of lead when digested for some time in vinegar.

It should be recollected that the glazes are often coloured, a variety of other poisonous metals entering into the composition of the colouring used, and here again we encounter an additional source of metallic contamination in some cases.

In reference to the glazing of cream-coloured earthenware, Accum has written:—'Pots of this kind of stoneware are wholly unfit to contain jellies of fruits, marmalade, and similar conserves. Pickles should in no case be deposited in cream-coloured earthenware.

'The baking of fruit tarts in cream-coloured earthenware, and the salting and preserving of meat are no less objectionable. All kinds of food which contain free vegetable acids or saline preparations attack utensils covered with a glaze in the composition of which lead enters as a component part.'

Another source of metallic contamination in cooked articles of food is the *solder* employed, especially in making tin vessels, the solder consisting of a mixture of *lead* and *tin*.

In *storing* as well as cooking, certain articles of food often become largely contaminated with various metals, especially with lead, zinc, and copper.

Lead is sometimes derived from the vessels made of that metal, or as already pointed out, from the glazing into the composition of which it enters.

Lead is a metal which used formerly to be very commonly employed in the formation of vessels intended for the preparation and storage of various articles of food, as particularly cider and milk.

After what has already been said, no further remarks need be made on the danger of the use of leaden vessels in the preparation of cider. The action of fresh and sweet milk upon the metal may perhaps be trifling, but if the milk become sour, lactic acid is formed, and this dissolves lead with the greatest ease, lactate of lead being very soluble in water.

A striking illustration of the effects of the storage of liquids in leaden vessels is afforded by the simple case of the retention in a wine bottle of a few of the shot used to cleanse it. The wine has been found to have become highly charged with both lead and *arsenic*, the shot in some cases being much dissolved and eaten away.

Another metal which used to be much employed, and which is still used for storage purposes, is *zinc*. Milk is still not unfrequently kept in pails and pans made of this material, the result being similar to that arising from the use of leaden vessels for the storage of milk, but in this case lactate of zinc becomes formed with even greater facility than the corresponding salt of lead. Very serious, if not fatal results have been known to follow the use of leaden and zinc vessels for the storage of milk.

It has been stated that the use of zinc vessels is attended with an increased yield of cream, amounting, it is said, to as much as twelve per cent. This result is thus explained; the acid formed as the milk turns sour is neutralised by the zinc, the coagulation of the milk is thereby prevented, and it remains consequently perfectly fluid and so allows of the easy ascent of the fat globules.

Formerly, and the same is still to some extent the case, vessels of copper were used for storage, a metal which, as we have seen, is easily oxidised and readily converted into soluble salts.

Another class of vessels constantly employed for the storage of liquids, especially malt beverages, is made of *pewter*, which consists of an alloy of *lead* and *tin*, with a little *antimony* and *copper*, and it forms the material of which all the pots of publicans are composed. This alloy is exceedingly soft, and is readily acted upon by the acids of the beer. When, as is usually the case, the vessels are kept perfectly clean and bright, and when the liquor is allowed to remain in them only for a few minutes, the metallic impregnation of the beverage is but slight, but if it remain in contact with them for some time, it will become charged with the metals.

Formerly it was not an uncommon thing for plates or platters to be made of pewter, and when the food was allowed to remain in the plates for some time, or was of a greasy or acid nature, a portion of the metal was very liable to become dissolved; and then again, particles of the metal were sometimes actually removed either in the course of cleansing the plates, or by the action of the knife in eating. It is still no unusual circumstance to meet with such plates, and we have ourselves often eaten off them. Their great recommendation, especially in former times, when crockery was not so cheap as it is now, was their not being liable to be broken.

It is also a common practice to store milk in *glazed* vessels. Here the same objection obtains, and danger arises, the lead of the glaze being quickly acted upon by the acids of the milk as in the case of storing milk in lead or other metallic vessels.

Such glazed vessels are very commonly used in the making of cheese, especially abroad: in some instances the milk is intentionally allowed to become sour, of course with an action correspondingly great on the glaze.

Vinegar, wine, spirits, and water are all very frequently stored in glazed earthenware bottles or jars, and they are all in consequence very liable to be contaminated thereby.

The acid of the vinegar would of course act speedily and greatly upon the glaze; wine and spirits also contain acids which would be liable to exert a similar action; while some of the acids and salts of water, especially the impure waters often sent to chemists for analysis, would lead to a like result. So much is this the case, that we have been constantly in the habit of insisting that the samples of water sent for analysis should always be stored in glass vessels. In the case of water, it is not alone the glazing which becomes dissolved, but sometimes a considerable quantity of the substance of the jar itself, lime and sulphuric acid being thus frequently introduced into the waters to be analysed.

Again, metallic contaminations are exceedingly apt to arise from the various metals which enter into the composition of the *pipes* and *taps* employed in the storage and conveyance of various liquid articles of food. It is in this manner that the presence of lead, copper, zinc, and tin is explained in vinegar and aërated waters.

Lastly, in Parkes' 'Chemical Essays' a curious practice is recorded whereby lead in the metallic state is introduced into an article of food. It appears that—

'In some parts of the North of England it is customary for the innkeeper to prepare the mint salad by bruising and grinding the vegetables in a large wooden bowl with a ball of lead of 12 or 14 lbs. weight. In this operation the metal is cut and portions of the lead are ground off at every revolution of the ponderous instrument. In the same country it is the common practice to have brewing coppers constructed with a bottom of copper, and the whole sides of lead.'

From all that has been advanced it will be evident that the greatest possible cleanliness should be insisted upon in the case of all metallic cooking utensils. No food ought to be allowed to stand in them for any length of time, especially when cold, since cold liquids absorb and retain more oxygen than when hot; the vessels ought, when the cooking is finished, to be emptied as soon as practicable and thoroughly cleansed with hot water, and be wiped quite dry, and they should not, as is too often the case, be allowed to clean themselves simply by the draining away of their contents.

It should not be forgotten that the action of nearly all the metals, when introduced into the human system, is cumulative, that is to say, that the dose of one day is added to that of the day following, so that, however small, and comparatively harmless the quantity of metal introduced at a meal may be, the time at length arrives when the system becomes so impregnated as to occasion injurious and even poisonous results. This view of the matter demonstrates the necessity of insisting upon the absolute freedom of all articles consumed as food from even the minutest amount of avoidable metallic contamination.

In reference to this point we may quote the following observations from Accum:—

'Though after all a single dose be not mortal, yet a quantity of poison, however small, when taken at every meal, must produce more fatal effects than are generally apprehended, and different constitutions are differently affected by minute quantities of substances that act powerfully on the system.'

We do not propose in this place to give the processes for the detection of the several metals to which we have referred, since they will be found fully described elsewhere in this work under their appropriate headings.

APPENDIX.

ON THE BLEACHING OF GINGER.

(*Reprinted from Travers & Son's Weekly Circular, May* 7, 1860.)

When water, sulphuric acid, and chloride of lime, which is a mixture of hypochlorito of calcium and of chloride of calcium, are mixed together, and agitated as in the process ordinarily adopted for the bleaching of ginger, several chemical changes ensue and continue in operation for some hours subsequent to the mixing of the ingredients.

Through the action of the sulphuric acid on the hypochlorite of calcium, hypochlorous acid is evolved, whilst the chloride of calcium present yields hydrochloric acid. Now, since hypochlorous and hydrochloric acids cannot exist together, water and chlorine are formed, the sulphuric acid uniting with the lime, sulphate of lime resulting. Lastly, when the sulphur is ignited to which the ginger is exposed in the last part of the process of bleaching, sulphurous acid gas is abundantly formed. Such, stated in as few words as possible, is an outline of the chief chemical changes attending the process usually pursued for the bleaching of ginger.

It is obvious from the ingredients employed, as well as from a consideration of the changes above alluded to, that in any analysis made for the purpose of ascertaining the effects of the process on the condition and wholesomeness of the bleached ginger, the principal points which require to be determined are the quantities of lime, chlorine, and sulphuric acid contained in the unbleached and bleached gingers. These, as also certain other particulars, will be found set forth in the following analyses:—

Unbleached Ginger 1,000 *grs.*

Chlorine	·45
Sulphuric acid	6·37
Lime	3·75
Total	10·57
Silica	1·20
Ash	31·80

The chlorine and sulphuric acid in the unbleached ginger are in the combined states and not in union with the lime.

Partly bleached Ginger.

Chlorine . .	7·50
Sulphuric acid .	8·96
Lime . . .	13·49
Total .	29·95
Silica . . .	2·04
Ash . . .	40·3

Bleached Ginger.

Chlorine . .	4·07
Sulphuric acid .	11·20
Lime . . .	12·82
Total .	28·09
Silica . . .	1·16
Ash	43·80

These results are strictly in accordance with what would naturally be anticipated from a knowledge of the process of bleaching followed. The analysis of the partly bleached ginger shows some increase in the amount of sulphuric acid, and a very large augmentation in the chlorine and lime; that of the bleached shows a still larger amount of sulphuric acid, as also would be anticipated from the fact of its having been subjected to the fumes of burning sulphur. The silica is least in the bleached ginger, as likewise we should expect would be the case.

Subtracting the amounts of chlorine, sulphuric acid, and lime found in the unbleached from those of the bleached gingers, it appears that the excess of those substances contained in the latter is as follows:—

Partly bleached.

Chlorine . .	7·05
Sulphuric acid .	1·59
Lime . . .	9·74
Total .	18·38

Or nearly 2 per cent.

Bleached.

Chlorine . .	3·62
Sulphuric acid .	4·83
Lime . . .	9·07
Total .	17·52

Presuming the chlorine to be in union with the lime, as also the sulphuric acid, and which, indeed, they are in part, they represent the subjoined amounts of chloride of calcium and sulphate of lime, leaving a large surplus of lime not combined with either the chlorine or the sulphuric acid:—

Partly bleached.

Chloride of calcium	10·96
Sulphate of lime .	2·70
Excess of lime .	4·72

Bleached.

Chloride of calcium	5·63
Sulphate of lime .	8·21
Surplus of lime .	3·68

It must be understood, however, that the chlorine is not all combined with lime, part of it being in the free state; the same remark applies to the sulphuric acid, part of which was not only in the free state, but existed in the form of sulphurous acid, especially in the bleached ginger, although, in the analysis, it was more convenient to convert it into sulphuric acid. The excess of lime, not combined with either the chlorine or sulphuric acid, is explained mainly by the fact that the chloride of lime used contained much caustic lime and carbonate of lime, and was, therefore, not chemically pure. The proportion of chlorine in the chloride of lime of commerce varies very greatly.

Calculating the quantities of sulphur, chlorine, sulphuric acid, and lime found in the partially and wholly bleached gingers for 1 cwt., we arrive at the following results:—

Partly bleached ginger.—Per cwt.	ozs.	drs.	grs.
Chlorine .	12	5	3
Sulphuric acid	2	6	47
Lime . .	17	3	36
	32	7	26
Equal to .	2lbs.	7	26

Bleached ginger.—Per cwt.	ozs.	drs.	grs.
Chlorine .	6	3	53
Sulphuric acid	8	5	13
Lime . .	16	2	0
	31	3	6

This gives rather more than one-fourth of an ounce of chlorine, sulphuric acid and lime to the pound of ginger.

The original amount of chloride of lime and sulphuric acid used were for the cwt. as follows:—

	lbs.	ozs.	drs.
Chloride of lime	5	9	5
Sulphuric acid	1 pint	1–5th.	

To these quantities must be added the sulphurous acid generated by the sulphur burned.

It follows therefore, that not nearly the whole of the ingredients used in the bleaching are taken up by the ginger during the process.

We have now before us all the elements necessary to enable us to arrive at a clear judgment as to whether the ginger is or is not rendered unwholesome by the process pursued.

From the calculations given, it appears that the entire addition of chlorine, sulphuric acid, and lime resulting from the bleaching is a little over a quarter of an ounce to the pound of ginger. Now this amount, although considerable, when we consider that ginger is a condimental substance, and that it is mixed with articles of diet only in very small quantities, is by no means sufficient to render the ginger unwholesome or injurious.

Nevertheless, except in appearance, which is certainly greatly improved, we consider that the unbleached ginger is much to be preferred, a conclusion confirmed by the fact that the agents used extract some of the active properties of the root.

An attentive consideration of the analyses shows that a chief objection to the process of bleaching adopted consists, mainly, in the large quantity of sulphurous acid added to the ginger, derived from the burning of the sulphur. In the course of time this becomes converted into sulphuric acid, which, in place of bleaching, tends to darken the ginger. Now were this part of the process either omitted or modified, one objection would be obviated.

There are two plans which might be followed with advantage.

The first is, that the ginger, after exposure to the fumes of sulphur, should be well washed in pure water. This would serve to remove the greater part of the free sulphurous acid.

The second plan consists in the substitution for the sulphur of the hyposulphites of soda or lime. This should be placed in water, the ginger added, and the sulphurous acid liberated by the addition of a little sulphuric acid. Finally, the ginger should be washed in water and dried. The sulphites are valuable and powerful bleaching agents.

THE DETECTION OF ALUM IN BREAD.

It appears that we now possess an easy and certain method for the detection of alum in bread. Professor Hadow, of King's College, London, formerly suggested the immersion of the bread in a decoction of logwood, when the presence of alum he affirmed would be indicated by the appearance of a blue coloration. But this process has long since been declared to be quite worthless, and had been generally abandoned, until Mr. Horsley, of Cheltenham, succeeded in improving it by certain modifications, so that by it we are now able to detect even very small quantities of alum in a very ready manner. The preparation of the necessary solutions is as follows: —An alcoholic solution of logwood is obtained by digesting half an ounce of logwood in 10 ounces of methylated spirit for eight hours and filtering. A saturated aqueous solution of ammonium carbonate is also prepared. A teaspoonful of each of these solutions is then diluted with about a wineglassful of water, and a thick slice of the crumb of the bread suspected to contain alum is then placed in the dark red liquid. The bread is allowed to soak till it is quite soft, which will be the case in about five minutes, and is then placed on a white plate. If alum be present in large quantity the bread will have assumed a dark indigo-blue colour, whilst with smaller amounts the colour will be more or less blue, but with very small quantities it is sometimes difficult to say whether the colour is red or blue.

We have tested this method carefully, examining the bread both chemically and by means of Mr. Horsley's method, and we have found that the one method corroborates the other.

THE ADULTERATION OF BEER.

During the last few years German and especially Bavarian beer has been largely adulterated with the flowers, tubers, and seeds of *Colchicum autumnale*, all of which contain the highly poisonous and bitter alkaloid *Colchicin*. Great quantities of this plant are gathered in meadows, where it is conspicuous in autumn by its purplish blue flowers, and in spring by its leaves and seed capsules. As far as we are aware, the alkaloid has not been detected in the beer itself, but of the employment of the plant no doubt whatever exists. Beans and peas are also largely used to adulterate Bavarian beer, and so to save malt.

When recently a large brewery at Munich was consumed by fire, and the fire-brigade officers gained entrance into the brewing-rooms, more peas and beans were found than malt, and the brewer, after some hesitation. acknowledged that he had employed them for a long time in the preparation of the wort.

Unfortunately the German sanitary laws are as yet so imperfect as to afford but little protection against such frauds.

GENERAL SUMMARY OF ADULTERATION.

Having now treated very fully of the adulterations practised upon nearly all articles of consumption, both Food and Drink, we are in a position to take with advantage a review of the whole subject, and to treat of adulteration in its more general and important aspects and relations. Thus—amongst other points—to define what constitutes adulteration; to prove its prevalence; to consider the excuses urged in extenuation and the real causes of its prevalence; who are the parties guilty of adulteration; to give a classification of the substances employed; to show the importance of the question in its commercial, sanitary, and moral bearings; and, lastly, to treat of the means which may be employed for the discovery and prevention of adulteration.

DEFINITION OF ADULTERATION.

1. The sale of one article in place of another is not an adulteration, but a substitution—as of chicory for coffee, of foreign animal fat for butter.

2. So, likewise, the abstraction of any portion or constituent of an article, as of the fatty matter or cream from milk, or the butter from cocoa.

3. The presence of substances in articles in consequence of impurities contained in the materials with which they were prepared, as, for example, of arsenic in the hydrochloric acid used in the preparation of unfermented bread, does not constitute adulteration; they are simply impurities.

4. The accidental presence of substances, in any commodity, as of earthy matter in pepper and tea, is not an adulteration.

5. The presence of substances derived from the vessels or utensils in which the articles are prepared or cooked, as of copper in vinegar, pickles, &c., of lead, arsenic, antimony, tin and other metals in various articles of consumption. These can hardly be termed accidental impurities, since they are the known and inevitable results of the use of such vessels.

Excluding, then, from the class of adulterations all cases of *substitution, abstraction,* of *impurities* and *contaminations,* whether accidental or resulting from the employment of certain vessels used for preservation, storing or cooking, adulteration may be thus defined:—

It consists in the intentional addition to an article of any substance or substances, the presence of which is *not acknowledged* in the name under which the article is sold, for purposes of gain, deception, or concealment.

It is not easy so to frame a definition which shall apply to every case: that now given does, however, most certainly embrace the great majority of adulterations practised, and it excludes substitutions, abstractions, impurities, and contaminations, because it specifies that the addition must be *intentional.*

According to this definition the sale of faced green tea, the presence of copper in bottled and tinned fruits or vegetables, of coffee containing chicory for and as coffee, of cocoa, into which sugar and starch have been purposely introduced, and of mustard, containing flour and turmeric, as cocoa and mustard, constitute so many adulterations.

The consumer entering a shop and asking for any article has a right to expect he will be supplied with that which he demands, and for which he pays; and he ought not to be furnished with a mixture of articles not acknowledged in the name under which the mixture is sold, and the nature and proportions of the ingredients entering into which are almost always unknown to him. This right undeniably belongs to the purchaser, and any wilful violation of it constitutes adulteration.

The words coffee, cocoa, and mustard convey distinct ideas: these names have been bestowed upon certain vegetable productions—coffee upon the berries of the coffee plant, cocoa and mustard upon the seeds bruised and reduced to powder of the cocoa and mustard plants: any application, therefore, of these words to mixtures and compounds is obviously improper, and in many cases is in a high degree deceptive.

The plea that the addition of chicory to coffee, of flour and sugar to cocoa, of turmeric and flour to mustard, as well as numerous other additions, constitute improvements, ought not to avail. In nineteen cases out of twenty, these additions are no improvements at all; and, where they really are so, the mixtures ought to be acknowledged in the names under which such mixed articles are sold; and not only ought this to be done, but the proportions of the several ingredients should in strict fairness be likewise stated.

In our opinion, therefore, in the sale of mixed articles, the law should require—(1.) That the mixed article should not be sold under the name of any one of its constituents; (2.) That the name given it should show that it is a mixture; and (3.) That the proportion of all the principal constituents should be stated.

Thus it should not be lawful, as it is now, to sell under the name of mustard a compound of wheat flour, turmeric, and cayenne pepper, with in some cases scarcely any mustard at all, or as coffee a mixture consisting almost exclusively of chicory, even although the admixture is acknowledged in general terms by affixing a label to the package, with a statement that the article is mixed. Such labels are usually printed in inconspicuous characters, and are placed upon some obscure part of the package, so that they frequently escape the notice of the purchaser, besides which, amongst the poor there are large numbers of people, and children particularly, who are unable to read at all.

The Sale of Food and Drugs Act fails to meet in this particular the requirements of justice, for although it stipulates that mixtures should be sold as such, it makes no provision as to the names under which they are sold, or as to the proportions of the ingredients. Thus, mixed mustard, coffee and cocoa will all be sold under the name of the unmixed and pure articles.

But any measure dealing with the subject of adulteration ought to contain provisions to meet cases of substitution, abstraction, and those impurities of food due to carelessness or permitted for certain special objects, as, for example, the removal of copper from the vessels for the purpose of greening pickles and preserves. The recent Sale of Food and Drugs Act does in fact take notice of substitution and abstraction, but it especially exempts impurities of all kinds, although their presence may be due to culpable negligence, or even to intentional admixture, as the large quantity of earthy matter frequently contained in pepper and tea, and in this respect, as in so many others, the Act in question is defective.

By including cases of substitution and abstraction, the framers of the Act referred to were enabled to get rid of the word adulteration altogether, which word, strange to say, is not once mentioned in the Act, although of course nearly the whole of the offences under it are cases of adulteration. This course was not at all necessary, as it would have been very easy to have included substitutions and abstractions under adulterations, but one need not go far to find the reason for the abandonment of the word adulteration. The Sale of Food and Drugs Act is for the most part the work of the manufacturers of articles of food—to them the word in question is an abomination, and so it was cleverly determined to burk it altogether. According to the Act referred to there is now no such thing as adulteration, this wholesome and meaning word being therein entirely abolished.

Another defect of the Act alluded to is that it does not contain any definitions of adulterations, as it ought to have done. A schedule should have been given, setting forth under the name of each article what constitutes adulteration. Such a document it would have been very easy to have prepared, and it would have put an end to the doubts, difficulties and contradictions which are certain to arise under the present Act, because it would define plainly what was prohibited in the case of every article. The schedule should have been framed in fact in the manner in which the definitions are drawn up which head the different chapters of this work.

PREVALENCE OF ADULTERATION.

The following particulars will serve to convey some idea of the great prevalence of adulteration.

During the course of the six years from 1850 to 1856 the author examined over 3,000 samples of the principal articles of consumption, as well as many drugs, and the one great result of this extended experience went to prove that during those years there were few articles of consumption the adulteration of which was practicable, and which, at the same time, could be rendered profitable, which were not extensively subjected to adulteration.

Since the period referred to he has analysed some thousands of additional samples with the gratifying result that adulteration does not now prevail to anything like its former extent, this result being due to several causes:—To the exposures made for so long a period in the 'Lancet'; to the increased facilities for detecting adulteration; to the several enquiries into the subject by Parliamentary Committees; and to the Acts which have been passed dealing with the subject. But although not nearly so prevalent as formerly, it yet does prevail to a large extent, and we believe that it is again increasing, and that much legalised adulteration will take place under the Sale of Food and Drugs Act, a measure framed in the interests of the manufacturers of, and dealers in, food.

The evidence of the former prevalence of adulteration does not, however, rest upon the testimony, undeniable as that evidence has been shown to be, of a single enquirer; but many scientific observers of undoubted capabilities, and in every respect trustworthy, have testified to the same effect; as, in this country, Accum, Mitchell, Normandy, Gray, O'Shaughnessy, Pereira, Thomson, Warington, Taylor, Calvert, Quekett, Bastick, Gay, Phillips of the Excise, and many others; and abroad, MM. Garnier and Harel and M. Chevallier.

The numerous witnesses examined before the Parliamentary Committee on Adulteration, of 1855, with one or two unimportant exceptions, concurred in their statements respecting the general prevalence of adulteration. Indeed, so conclusive was the evidence deemed that the Committee admitted that they had been constrained to acknowledge that the statements made as to the extensive practice of adulteration had been fully confirmed by the enquiry, and that legislation had been rendered imperative.

The Committee stated, in their Report, that they 'cannot avoid the conclusion that adulteration widely prevails.' 'Not only is the public health thus exposed to danger, and pecuniary fraud committed on the whole community, but the public morality is tainted, and the high commercial character of the country seriously lowered both at home and in the eyes of foreign countries.'

These are grave statements and admissions, made on the very highest authority.

Of course no evidence can be more satisfactory or conclusive than that of witnesses who speak to what they themselves have ascertained in the course of their investigations; there is, however, evidence of the existence of adulteration of another kind, and that is the occasional supply of articles of consumption to workhouses and other public establishments *under* market price. We have become acquainted with more than one instance of this kind, especially in the articles arrowroot and oatmeal; the difference in price being ascertained to have been made up by adulteration.

Dr. Normandy concluded his evidence before the Parliamentary Committee referred to with this remark:—

'Adulteration is a wide-spread evil, which has invaded every branch of commerce; everything which can be mixed or adulterated or debased in any way, is debased.' To the general accuracy of this declaration our own experience compelled us to subscribe.

It may in the next place be considered how it happens that adulteration is so prevalent.

Various reasons have been assigned to account for this prevalence: the majority of these have been suggested by parties more or less interested in adulteration, either directly or indirectly; the principal of them we shall proceed to notice, and first those reasons, or rather excuses, which have been urged in defence of adulteration.

EXCUSES URGED IN EXTENUATION OF ADULTERATION.

One reason assigned in defence of many adulterations is that they are practised in obedience to the wishes and tastes of the public.

Another, that the additions made to several articles constitute improvements.

It is on the first of these pleas that the practice of colouring red sauces, potted meats, and fish with bole armenian; cheese with annatto; pickles, bottled fruits, and vegetables with copper; and sugar confectionery with various pigments consisting of salts of arsenic, copper, lead, and antimony, is excused.

Now, although it may be true that the public, in some instances, prefer the more highly coloured article, yet they do so as a mere question of appearance, and in total ignorance of the means by which these colours are obtained; these means explained, and the public made aware of the fact that they are produced by some of the most poisonous substances known, it is not correct to say that they would knowingly sanction the use of these poisons, and would prefer, merely for the sake of colour, articles which were known to contain injurious substances to those which are pure and wholesome.

It is on the second of these pleas, viz., that the additions made to several articles constitute so many improvements, that the addition of chicory to coffee is defended; wheat-flour and turmeric to mustard; sugar and starch to cocoa; sulphuric acid to vinegar. We have already treated of the addition of chicory to coffee, and of sugar and starch to cocoa; and have shown that it is very questionable whether chicory is an improvement to coffee, and whether it is not positively hurtful; if it be an improvement, still it is proper that each of the articles called chicory and coffee should be sold by itself, and used or not by the public as it might wish. In the case of cocoa it has been proved that the sugar and starch are employed in many cases to such an extent that the compound of starch, sugar, and cocoa scarcely retains the flavour or smell of the latter substance, while its colour is so altered and reduced, that it becomes necessary to have recourse to coloured earths to bring it up to its proper standard.

The manufacturer tells us that mustard by itself is so disagreeable that we could not eat it, and hence the use of wheat-flour and turmeric. But the answer to this statement is that, in some of the so-called mustards, the turmeric and wheat-flour are so out of proportion that the compound scarcely retains the flavour of mustard. Again, that genuine mustard cannot be so unpalatable a thing is proved by the fact that there are now some manufacturers who profess to sell nothing but the genuine article.

Another plea urged in extenuation of certain additions is, that they are necessary in order to make the articles keep. It was on this ground that the legislature was brought to sanction the addition of sulphuric acid to vinegar; but that it has no real foundation in this case is shown by the fact that there are now manufacturers conducting extensive establishments who do not add even the smallest proportion of sulphuric acid to their vinegar.

When, therefore, the manufacturer or seller defends any particular admixture or adulteration, on any of the pleas referred to, namely, that it is practised to suit the public taste, that it is an improvement, or that it is necessary in order to make the article keep, we would advise our readers to look well into the matter for themselves. They will be almost sure to find something wrong, some fallacy at the bottom of these statements. They will too often find that this pretended regard for the wishes and tastes of the public resolves itself into a question of gain to the manufacturer or trader.

Another plea sometimes urged in extenuation of adulteration, and perhaps there is something in it, but not much, is that it is impossible to supply genuine articles at the prices the public are willing to pay for them.

No doubt the public like to obtain what they require at as cheap a rate as possible,—but it is for the trader to fix the prices at which he can afford to sell his goods, and not the public; further, if it were explained to the public by the dealer that he could not answer for the quality or purity of the very cheap articles sold, there are, we believe, very few persons who would be so silly as to prefer the adulterated to the genuine article, although the former might be apparently the cheaper.

We say *apparently cheaper,* because in many cases these so-called cheap articles are really the dearest in the end, for, owing to the extent to which they are adulterated, they do not go nearly so far as genuine articles would do. The public then, we consider, is but little at fault. It merely requires to be made acquainted with the true and actual state of things, and there is no doubt but that in ninety-nine out of every hundred cases it would prefer the genuine to the adulterated commodity, even although for this a somewhat higher price had to be paid.

A further excuse sometimes urged in defence of certain adulterations is that they do no harm. By this plea we suppose is meant that they are not hurtful to the health, but only to the pocket. On this ground the adulteration of milk with water is sometimes defended. Now we are of opinion that there are few more scandalous and indirectly injurious adulterations than this. Milk is an important and prime article of diet, full of nourishment, and in proportion as water is added, so are those who partake of the diluted compound robbed of their proper nourishment.

Such are some of the excuses employed in defence of adulteration. That they should be urged by certain manufacturers and traders, whose profits in some cases are so largely dependent upon adulteration, is not so surprising; but what really is astonishing is that there should be found some few men, very few, we are happy to state, of more or less scientific repute, who, influenced by certain considerations of interest, lend the weight of their names and use their scientific attainments in defence of adulteration.

Science is never so rightly or so nobly employed as when it ministers to the wants and well-being of mankind, and especially when it is used for the protection of the public health. On the other hand, is it not an unworthy and an ignoble use to make of science to employ it in defence of practices which even those who defend them most in their own consciences must condemn? And yet there are men who thus demean themselves.

Thus they endeavour, if possible, to get up a cry of exaggeration, and this in the face of evidence of the most conclusive and demonstrative character.

Another course pursued is to cite some of the less important instances of adulteration, as, for example, the addition of alum to bread, of water to spirits, and to argue from them as though they were not, as they really are, parts of a system, but as if they were the worst instances of adulteration, and as though the entire case rested upon them.

Another favourite plea used in extenuation of adulteration is that the quantities in which some of the substances are employed, as those used for the sake of colour, are too inconsiderable to be productive of hurtful results.

This is so sometimes, but it certainly is not the case in the majority of instances. In many cases injurious consequences have been actually proved to ensue; thus many persons have been poisoned outright, and have lost their lives, from the use of coloured sugar confectionery; others have been rendered seriously ill. Cases of lead paralysis have been produced by the lead purposely introduced into snuff, and the same, it has been asserted, has occurred from the use of cayenne coloured or adulterated with red lead. Again, illness of a serious, and even fatal, character has been produced by the use of poisonous adulterants not pigments, as from lead in wine, cocculus indicus in beer and spirits. Indeed, instances might be multiplied to a large extent of disease originating in the use of substances employed for adulteration. Who can tell how many invalids and tender children have fallen victims to the dangerous adulterations practised upon food, drinks, and drugs, if the true causes of premature death could be traced out in all such cases? That dyspeptic ailments often owe their origin to the adulteration of articles of food is unquestionable.

Besides, if the employment of poisonous pigments and other substances is to be permitted at all, what guarantee or security have we against accidents resulting from the careless and ignorant use of such poisonous or injurious articles? The only right and safe principle upon which to act we maintain is to discard the use of all additions to articles of consumption that are unnecessary, or which may possibly become a source of danger. Again, it must be remembered that the ill effects of adulteration cannot be estimated by the quantity of any particular ingredient contained in any one article. So prevalent is adulteration, that in the course of a single day it often happens that several injurious ingredients are partaken of, and in order to arrive at any correct conclusion we must therefore take the sum of the whole of these ingredients.

Lastly, in endeavouring to estimate the effects of adulteration on health, the fact must be borne in mind that some of the metallic poisons used are what are called *cumulative.*

We have been induced to enter into an examination of the various pleas on which the practice of adulteration is sometimes defended, in order that when the readers of this work hear them urged, as some of them doubtless will, they may know what they are really worth, and how they may be refuted.

Having noticed the various pleas on which adulteration is defended, we have still to consider to what cause or causes its prevalence is due.

REAL CAUSES OF THE PREVALENCE OF ADULTERATION.

The great cause which accounts for the larger part of the adulteration which prevails is the desire of increased profit; a second cause is excessive and unfair competition. A trader, perceiving that his neighbour in the same business is selling his goods at prices at which, if genuine, it would be impossible to realise a profit, knows that this can only be done by having recourse to adulteration, and finding that he cannot compete with his unscrupulous fellow-trader, at length he himself too often has recourse to the same practice. We thus perceive how difficult it is for many tradesmen who desire to do so to conduct their business in an honourable way, and to resist the temptation to adulterate. The main causes of the prevalence of adulteration are, then, the desire of increased profit and excessive and unfair competition.

WHO ARE THE PARTIES GUILTY OF ADULTERATION?

The next question for consideration is: Who are the parties guilty of adulteration?

The answer is, in some cases, the manufacturers, and in others the retail dealers. This distinction is of the utmost importance, especially with reference to the means to be adopted for the discovery and suppression of adulteration.

Some of the adulterations practised require to be so on the large scale, and involve the use of extensive machinery, which the tradesman does not possess; and in consequence certain adulterations, as of flour, of chicory, of cocoa, of spices, and of many drugs, are practised by the grinders and roasters of those articles; there is a class of persons known as spice and drug grinders, with whom lies much of the fault of the adulteration of spices and drugs.

In the drug trade the practice at one time was very general, and it still prevails to some extent, of adding sawdust of different kinds, as well as other articles, in order, it was urged in excuse, to make up for the varying and average loss sustained by different drugs in the course of drying and grinding to a uniform loss of 4 per cent. This is called the 4 per cent. system; however, the practice does not stop here, but leads to every species and degree of abuse.

The adulterations of mustard, vinegar, annatto, snuff, coloured sugar confectionery, and some other articles, are also usually practised by the manufacturers.

There are good reasons why, in many cases, the manufacturer should be the adulterator. Not only has he the necessary machinery and other means of performing the requisite operations on a large scale, but the responsibility of adulteration is thus taken off the shoulders of the tens of thousands of traders by whom the public is immediately supplied, and is confined in some degree to the comparatively small body of manufacturers, whose proceedings are conducted in retirement and secrecy, and whose premises are not accessible to the public.

The retail trader, however, takes in many cases his share in the work of adulteration; as one example, we may mention that much of the adulteration of beer and spirits is perpetrated by the publican. Even in those cases in which the retailer does not himself adulterate, he often purchases of adulterating merchants with guilty knowledge; thus, in many cases, he is aware of the fact that the article he purchases is adulterated from the price paid for it being less than that at which the genuine article can be procured. In such cases the tradesman is a party to the fraud, and is as guilty as the actual perpetrator of the adulteration.

It should be known that even the purchasing of articles of consumption in the raw state by the trader affords no certain guarantee for the genuineness of those articles, provided they are afterwards sent to the grinder or manufacturer to be ground or manufatured. We have known tradesmen who, wishing to protect themselves as far as possible against adulteration, have purchased the best cocoa beans and chicory nibs, and have then sent them to the grinder to be prepared, but, upon being returned to them, they were found to be adulterated. Messrs. Ridgway & Co., of King William Street, forwarded to the author, some years since, some flake cocoa for examination: this was found to be adulterated with wheat-flour. Messrs. Ridgway then stated that they had purchased the best cocoa beans they could procure, and sent them to the manufacturer to be made into *flake* cocoa, which should consist of nothing but cocoa. The manufacturer, in this case, had subtracted some of the cocoa, and had replaced it with wheat-flour. Since this occurred Messrs. Ridgway have had a mill erected on their premises, so as to be enabled to make their own flake cocoa.

Now it must not be inferred from these remarks that there are not many honest manufacturers and traders connected with the manufacture and sale of articles of consumption. We know that there are many such, and on behalf of some of those who either are really guilty of, or who lend themselves to adulteration, the excuses may be urged that until very recently the legislature has been indifferent to this subject, and did not protect the honest trader, and that in self-defence, and for very livelihood's sake, he is often driven to adulterate.

CLASSIFICATION OF ADULTERATION.

Not only is adulteration prevalent, but *the articles employed are very numerous*—different kinds of substances being used for different purposes. The majority of substances used are so for one of three purposes: either for the sake of *bulk* or *weight*, the articles used of course being cheaper than those to which they are added; for the sake of *colour*, that is, to heighten and improve the appearance of articles as it is considered, often erroneously, the natural colour of such articles being frequently altered and reduced by dilution with other adulterating substances added for bulk and weight; or, lastly, to increase the *pungency* of articles and to heighten their *properties* and *flavour*.

The first kind of adulteration is the more usual form, and is that by which the practice is rendered so profitable; the second, that which consists in the addition of colouring matters of various kinds, is often necessitated by the first kind, so that these two descriptions of adulteration frequently go together.

An example of the first kind of adulteration is furnished by the addition of roasted corn to chicory or coffee powders, and of water to milk.

Of the second, in the addition of red lead to cayenne, Venetian red, umber, &c., to chicory and cocoa; while an example of the third form of adulteration is met with in the addition of alkalies, as also the chromates of potash, hellebore, and powdered glass to snuff.

Now it is in the second class, viz., that which consists in the employment of colouring matters of various kinds, that the majority of those adulterations are included which are prejudicial to health; this will be seen more clearly hereafter.

So numerous and various are the substances employed for adulteration that a classification of them according to the article in which they are encountered, and the purpose to which they are applied, becomes useful. Such a classification is given in the following tables.

The annexed table contains only the names of those substances which we have ourselves ascertained, by original observations and analyses, to be actually employed for the adulteration of articles of food; it does not include drugs.

Classified List of the various Substances ascertained by Ourselves to be Employed for the different Purposes of Adulteration: viz. for Bulk and Weight, for Colour, or for Smell, Taste, and other Properties.

	For Bulk and Weight.	For Colour.	For Taste, Smell, and other Properties.
ANNATTO. .	Rye, Wheat, and Barley Flours, Turmeric, Carbonate and Sulphate of Lime, Red ferruginous Earths, Red Lead, Salt.	Turmeric, Red ferruginous Earths, Salt, Alkali.	Sulphate of Copper.
ARROWROOT .	Sago, Potato, and Tapioca Starches, and various mixtures and combinations of these with the inferior Arrowroots.		
ANCHOVIES .	Dutch, French, and Sicilian Fish.	Bole Armenian, Venetian Red.	
BRANDY . .	Water.	.. ..	Burnt Sugar.
BREAD . .	Mashed Potatoes, Rice, Beans, Rye, Indian Corn.	.. ..	Alum, Hards and Stuff.
BUTTER . .	Water, Foreign Fat, Curd, and excess of Salt.		
BOTTLED FRUITS AND VEGETABLES	.. ..	Salts of Copper, usually the Acetate or Sulphate.	Salt.
CHEESE . .	.. ..	Annatto, Bole Armenian, Venetian Red.	Sage, Parsley.
COLOURED CONFECTIONERY.	East India Arrowroot, Wheat and Potato Flour, Hydrated Sulphate of Lime.	Cochineal, Lake, Indigo, Prussian Blue, Antwerp Blue. Artificial Ultramarine, Carbonate of Copper or Verditer, Carbonate of Lead, or White Lead, Red Lead, Vermilion; Chromates of Lead, Lemon, Orange and deep; Gamboge; Sap Green; the three Brunswick Greens, Emerald Green or Arsenite of Copper, Indian Red; brown ferruginous Earths, chiefly Umber, Sienna, and Vandyke Brown, and various combinations of the above pigments.	Artificial Essences, as Acetate of Ethyl, Butyrate of Amyl, Acetate of Amyl, Valerianate of Amyl.

List of Substances (continued).

	For Bulk and Weight.	For Colour.	For Taste, Smell, and other Properties.
CINNAMON	Cassia, and most of the articles mentioned under Spices.		
COFFEE	Chicory, Roasted Wheat, Rye and Potato Flours, Roasted Beans, Mangel-wurzel, Acorns.	Burnt Sugar or Black Jack, Venetian Red.	
CHICORY	Roasted Wheat and Rye Flours, Burnt Beans and Acorns, Sawdust, Mahogany Sawdust, Carrots, Mangel-wurzel.	Ferruginous Earths, as Venetian Red and Umber, Burnt Sugar or Black Jack.	
COCOA AND CHOCOLATE.	Maranta, East India, and Tacca or Tahiti Arrowroots; Tous les Mois; the Flours of Wheat, Indian Corn, Sago, Potato, and Tapioca, and various Mixtures of these; Sugar, Chicory, Cocoa Husks.	Venetian Red, Red Ochre, and other ferruginous Earths.	
CAYENNE PEPPER.	Ground Rice, Mustard Husk, Salt.	Red Lead, Vermilion or Bisulphuret of Mercury, Venetian Red, Turmeric.	
CUSTARD AND EGG POWDERS.	Wheat, Potato, and Rice Flours.	Chrome Yellow or Chromate of Lead, Turmeric.	
CURRY POWDER.	Ground Rice, Potato-farina, Salt.	Red Lead.	Salt.
FLOUR	Rice, Beans, Rye, Indian Corn, Potato Flour.	.. ..	Alum.
GINGER	Wheat, Sago, and Potato Flours, Ground Rice, Mustard Husks.	Turmeric Powder.	Cayenne Pepper.
GIN	Water, Sugar.	.. ..	Cayenne, Cassia or Cinnamon, Sugar, and flavouring of different kinds. For fining, Alum, Salt of Tartar.
HONEY	Cane Sugar.		
ISINGLASS	Gelatine.		

List of Substances (continued).

	For Bulk and Weight.	For Colour.	For Taste, Smell, and other Properties.
LARD . .	Potato Flour Water.	Alum.	Salt, Carbonate of Soda, Caustic Lime.
LEMON AND LIME JUICES	Water.	.. ..	Sulphuric Acid.
LIQUORICE .	Wheat Flour, Potato Starch, boiled Starch, probably Rice, Chalk, and Gelatine.		
MALT BEVERAGES.	Water, Sugar, Treacle.	Burnt Sugar, Liquorice.	Alum, Sulphate of Iron, Salt.
MUSTARD .	Wheat Flour, Turmeric, Cayenne Pepper.	Turmeric.	
MILK . .	Water.	Annatto.	
MARMALADE .	Pulp of Apple or Turnip.		
OATMEAL. .	Barley Flour, and the integuments of Barley called Rubble.		
PORTER AND STOUT.	Water.	Sugar, Treacle.	Sugar, Treacle, Salt.
PICKLES . .	.. ..	Salts of Copper, usually the Acetate of Copper.	
POTTED MEATS AND FISH.	Flour, probably Wheat Flour, boiled.	Bole Armenian, and sometimes Venetian Red.	
PRESERVES .	Inferior and cheaper Fruit, Apple, &c.	Salts of Copper, including the Acetate, Fuchsine.	
PEPPER . .	Wheat and Pea Flour, Ground Rice, Ground Mustard Seeds, Linseed Meal, P. D., or Pepper-Dust, Sand, Woody Fibre.		
SAGO . .	Potato Flour.		
TINNED VEGETABLES.	.. ..	Sulphate of Copper.	
RUM . .	Water.	.. ..	Cayenne, Burnt Sugar.
SUGAR . .	Wheat Flour, Potato Flour, and Tapioca Starch.		

List of Substances (continued).

	For Bulk and Weight.	For Colour.	For Taste, Smell, and other Properties.
SPICES:			
CLOVES .	Powdered Clove-stalks in one case.		
CINNAMON .	Cassia, Wheat Flour, Sago Meal, and mixtures of these; East India Arrowroot, Potato Flour.		
PIMENTO .	Mustard Husk in one instance.		
MIXED SPICE .	Wheat, Sago, and Potato Flours, Ground Rice, two Vegetable Substances, one of which resembled Linseed.		
SAUCES, as the Essences of Anchovies, Lobsters, and Shrimps, and Tomato Sauce.	.. ..	Red ferruginous Earths, as Bole Armenian and Venetian Red.	
TEA. . .	Exhausted Tea Leaves; Leaves, other than those of Tea, British and Foreign, amongst the former those of Sycamore, Horse-Chestnut, and Plum; Lie Tea, Paddy Husk, Sand, Quartz, Magnetic Oxide of Iron, Starch.	Plumbago or Black Lead, Gum, Indigo, Prussian Blue, Turmeric, Chinese Yellow, China Clay, Soap-stone or French Chalk, Mica and Sulphate of Lime.	Sulphate of Iron, Catechu, Gum, La Veno Beno, Chinese Botanical Powder.
VINEGAR .	Water.	Burnt Sugar.	Sulphuric and Pyroligneous Acid.
WINE . .	Extraneous Spirit, Water.	.. ..	Cane Sugar, Sulphate of Potash.

Of the two following tables the one is of articles ascertained to be used by others; the second, of articles stated to be employed by different writers, but of the use of which no positive proof is given, although there is no doubt but that most of them either have been or are occasionally employed.

List of Articles ascertained by Others to be used for the Purpose of Adulteration.

	For Bulk and Weight.	For Colour.	For Taste, Smell, and other Properties.
BOTTLED FRUITS AND VEGETABLES	.. ..	Decoction of Logwood, Beetroot, and Aniline Colouring.	
BREAD . .	.. ..	Sulphate of Copper.	
CHEESE . .	Potatoes, Beans.	Mangold Flowers, Saffron, Red Carrots.	Sage, Parsley.
CHICORY . .	Coffee Flights.	Hambro' Powder.	
FLOUR . .	Mineral White or Hydrated Sulphate of Lime.		
GIN . . .	.. ..	.. ..	Grains of Paradise, Sulphuric Acid, various Gin Flavourings, containing Coriander Seeds, Angelica Root, Oil of Almonds, Calamus Root, Almond Cake, Orris Root, Cardamom Seeds, Orange Peel, Grey and White Salts.
LARD . .	Mutton Suet.	Alum, Potash.	
MALT BEVERAGES.	.. ..	.. ..	Cocculus Indicus, Picric Acid, Colchicum, Tobacco.
MILK AND CREAM.	Flour or Starch, Boiled White Carrots, Treacle, Gum and Dextrin.		
MUSTARD .	Ginger, Charlock, Potato Flour, Rice, Clay, Plaster of Paris.		
OATMEAL .	Rice and Maize.		

List of Substances (continued).

	For Bulk and Weight.	For Colour.	For Taste, Smell, and other Properties.
PORTER AND ALE.	.. ..	.. ..	Cocculus Indicus, Grains of Paradise, Capsicum, Ginger, Quassia, Wormwood, Calamus Root, Caraway and Coriander Seeds, Ginger, Orange Powder, Liquorice, Honey, Sulphate of Iron, Sulphuric Acid, Cream of Tartar, Alum, Carbonate of Potash, Oyster Shells, Hartshorn Shavings, Fabia amara or Nux Vomica, Beans.
RUM . .	.. ..	.. ..	Cocculus Indicus.
SUGAR . .	Potato Sugar, Gum, Dextrin.		
TEA . .	The Leaves of Beech, Plane, Bastard Plane, Elm, Poplar, Willow, Fancy Oak, Hawthorn, Sloe.	Rose Pink, Dutch Pink, Vegetable Red and Yellow Dyes, Chrome Yellow, Venetian Red, Carbonate of Copper, Arsenite of Copper, Chromate and Bichromate of Potash, Carbonates of Lime and Magnesia.	
WINE . .	Jerupiga, Cider, mixtures of inferior and different Wines, the juice of Rhubarb, Gooseberries, Apples, and Pears.	Elderberry Juice, Logwood, Brazil Wood, Bilberries, Burnt Sugar, Black Cherries, Cochineal, Mallow Flowers.	Lead, Bitartrate of Potash, Oak Sawdust, Catechu, Cherry Laurel Water, Carbonates of Soda and Potash, Artificial Flavouring.

List of Articles stated by Others to be employed for the different Purposes of Adulteration, but of the Use of which no Positive Evidence has been adduced, although it is extremely probable that many of them have been, or are occasionally, had recourse to.

	For Bulk and Weight.	For Colour.	For Taste, Smell, and other Properties.
ARROWROOT	Ground Rice.		
ANCHOVIES .	Sprats, Sardines, Plaster of Paris.		
BREAD . .	Barley, Oat, Pea Flour, Pipe Clay, Plaster of Paris, Bonedust, Carbonates of Lime, Magnesia, and Soda.		
COLOURED CONFECTIONERY.	White Potter's Clay, Pipe Clay, or Cornish Clay; Chalk, Sand.	Cobalt, Smalt, Litmus, Naples Yellow.	
COFFEE . .	Roasted Peas, Coffee Grounds, Carrots, Beetroot, Parsnip, Baked Liver.	Madder Root.	
CHICORY . .	Torrefied Ground Rice, Roasted Biscuit, Oak Bark Tan, Exhausted Tan, called Croats.	Baked Horses' Liver, Burnt Blood.	
COCOA AND CHOCOLATE.	Old Sea Biscuits, Coarse Branny Flour, Animal Fats, as Tallow, Lard, Treacle, Sulphate of Lime, Chalk.	Red Lead, Vermilion, Red and Yellow Ochre.	
FLOUR .	Chalk, Bone Earth, Plaster of Paris, Powdered Flints.		
GIN . . .	.. ..	.. ..	Acetate of Lead, Oil of Turpentine.
HONEY . .	Chalk, Sulphate of Lime, and Pipe Clay.		
LEMON AND LIME JUICES.	.. ..	.. ..	Tartaric Acid, Hydrochloric and Nitric Acids
LITMUS .	.. ..	.. ..	Common Arsenic and Peroxide of Mercury.

List of Substances (continued).

	For Bulk and Weight.	For Colour.	For Taste, Smell, and other Properties.
MALT BEVERAGES.	.. ..	.. ..	Gentian, Chiretta, Quassia, Wormwood, Orange Peel, Camomile, Opium.
MUSTARD .	Pea Flour, Linseed Meal, Radish Seeds.	Chromate of Lead.	
MILK . .	Sheep's Brains, Gum Tragacanth, Milk of Almonds.	Turmeric.	
PEPPER . .	Ground Oil Cake, Clay.		
RASPBERRY JELLY.	Currant Jelly.	.. ..	Orris Root.
SUGAR . .	Sand, Plaster of Paris, Powdered Marble, Chalk, Bonedust, and Common Salt.		
SAUCES . .	Chalk, Plaster of Paris.	Red Lead.	
VINEGAR .	.. ..	.. ..	Acetic, Hydrochloric, Nitric, and Tartaric Acids; Cayenne, Long Pepper, Mustard Seed, Salt.

Another arrangement or classification of substances used for adulteration is into those that are not injurious, but the use of which is simply fraudulent, and into those which are hurtful to health. A list of all the substances employed for adulteration, which are more or less prejudicial to health, will be given hereafter.

IMPORTANCE OF THE SUBJECT OF ADULTERATION.

The subject of adulteration is undoubtedly one of such high importance, that it may fairly engage the earnest thoughts of the financier, the sanitarian, and the moralist.

The financier, because it involves to a large extent considerations of profit and loss; profit to the manufacturer and seller of adulterated articles, and loss to the consumer and the revenue.

The sanitarian, because some of the articles employed in adulteration are of an exceedingly injurious character, and calculated to affect materially the public health.

And the moralist, since the practice of adulteration involves deception, and even fraud.

Adulteration is therefore a great national question, closely affecting the pocket of the consumer, the revenue, and the health and morals of the people. We shall now proceed to enlarge upon each of these heads.

THE PECUNIARY BEARINGS OF ADULTERATION.

The pecuniary bearings of the subject of adulteration are of very great importance, and they relate to the consumer, the manufacturer, merchant or tradesman, and the revenue.

The great profit of adulteration arises from the sale of articles so adulterated as to be greatly inferior in value to genuine commodities, a price being demanded for these mixed goods yielding a larger profit than could be obtained by the sale of unadulterated goods; in fact, they are often sold at the rate of the pure articles. This increased profit to the seller is just so much loss to the consumer.

So great is the loss of the consumer arising out of the practice of adulteration that it is questionable whether it does not amount in most cases to more than the sum of the whole of his taxes. The greatest losers by adulteration are the humbler classes, the labourer and the artisan, who are compelled to purchase the articles they use at the cheapest shops, where adulteration prevails to the greatest extent. This practice, therefore, presses with peculiar hardship upon the labouring portion of the population.

It is clear that the sellers of adulterated articles of consumption, be they manufacturers or retail dealers, are in a position to enhance their profits by the practice of adulteration, and are enabled to undersell, and too often to ruin, their more scrupulous and honest competitors.

The question of the adulteration of food is therefore one which vitally affects the interests of *the more honest and respectable portion of the trading community*, who depend upon the manufacture and sale of articles of consumption, and it behoves them strenuously to exert themselves to put an end to a system of adulteration, which undermines the very foundation of trade, namely, FAITH IN COMMERCIAL INTEGRITY.

The pecuniary interests of the State in the question of adulteration will become apparent when we remember that a large part of the revenue is derived from duties on articles of consumption. The more these articles are adulterated, the more is the revenue defrauded.

It is not possible to estimate with certainty the precise loss to the State arising out of adulteration; but from the millions of money derived from duties on articles of consumption amounting, according to the author of the 'Food of London,' to half the national revenue, and from the extent to which adulteration has prevailed, and still prevails, the loss must amount annually to an enormous sum of money.

Mr. P. L. Simmonds, in his evidence before the Parliamentary Committee in 1855, handed in some calculations, whereby he made the loss to amount in the year 1854 to upwards of three millions; but this estimate we believe to have been too low at the date at which the calculations were made. At about the same date we also considered well this question, and, assigning to each article a certain percentage of adulteration, based upon the returns for the year 1855, and of many thousands of analyses, we arrived at the conclusion that the total loss to the revenue arising out of adulteration amounted to about seven millions. This estimate for the present time is no doubt too high; but the loss may still be calculated at millions, if we include tea, coffee, cocoa, pepper, malt, malt beverages, hops, spirits, wine, and tobacco, which are the main heads under which the loss is sustained, and from which the revenue is derived.

These few facts are sufficient to show the paramount importance of adulteration to the national exchequer.

If the State loses so much, it is pretty certain that the public suffers a much greater loss.

THE SANITARY BEARINGS OF ADULTERATION.

We now come to consider the question of adulteration *as it affects the public health.* No doubt can possibly be entertained on this subject; no one who examines with sufficient care the facts but must acknowledge that the subject of adulteration is of the highest importance in a sanitary point of view, and as a question of public health.

In the first place, the adulteration of articles with substances, although harmless in themselves, is frequently prejudicial, by reducing and weakening the natural properties of those articles. This is the case when roasted corn or carrot is added to coffee, and water to milk: but the remark applies especially to medicines; for in this case to reduce the strength of a medicine by adulteration is to destroy or modify the proper action of that medicine. The proper doses of different remedial agents have been determined, in most cases, by careful observation and experiment; and in different doses the same medicine is known to produce very different effects. To adulterate medicines, even with harmless substances, is to destroy the very foundation of the healing art, and so to render nugatory the wisest and best directed efforts of the physician.

In the second place, adulteration acts prejudicially to the public health when substances are employed possessing injurious properties. Now a great variety of such substances are used for the purpose of adulteration. We have ourselves detected, amongst others, the following:—The three chromates of lead, the three Brunswick greens, which are mixtures of the chromates of lead and indigo or Prussian blue, red oxide of lead or red lead, arsenite of copper, sulphate of copper, acetate of copper, carbonate of copper or verditer, carbonate of lead or white lead, bisulphuret of mercury, cinnabar or vermilion, sulphate of iron, gamboge, cayenne in spirits, bronze powders, which are alloys of copper and zinc, sulphate of lime, carbonate of lime, red ferruginous earths, and other substances more or less injurious. This list, it will be observed, contains the names of some of the most virulent poisons. Sometimes the quantities of these substances used are so considerable that immediate ill effects are produced: thus, as has already been stated, scarcely a year passes but that serious, and even fatal, accidents arise out of the practice of colouring sugar confectionery with poisonous pigments. More frequently the effects are more slowly developed: the substances, although taken perhaps in but minute quantity, gradually and insidiously deteriorate the health, giving rise frequently, amongst other maladies, to various forms of dyspepsia or indigestion: sometimes, as in the case of lead, copper, mercury, and arsenic, they accumulate in the system until at length serious consequences are produced; thus cases of paralysis have been traced in the clearest manner to the use of snuff adulterated with preparations of lead; some of these cases will be found recorded in 'Food and its Adulterations;' other cases of lead paralysis, it has been stated, have been produced by the use of cayenne adulterated with red lead.

The subjoined table contains not only the names of the substances used in adulteration possessing more or less injurious properties, but also the names of the articles in which they have been discovered. It will be perceived that the number of such substances is very great.

Now with evidence such as the above, it is impossible to contend that the use of such a variety of injurious, and even poisonous, substances is unattended with danger, and that adulteration does not affect the public health. It may so happen, and it has doubtless not unfrequently occurred, that the same person, in the course of a single day, receives into his stomach several of the articles above enumerated. Thus, with the potted meats and fish, anchovies, red sauces, or cayenne, taken at breakfast, he would consume more or less bole Armenian, Venetian red, red lead, or even bisulphuret of mercury. At dinner, with his curry or cayenne, he would run the chances of a second dose of lead or mercury; with the pickles, bottled fruits and vegetables, he would be nearly sure to have copper administered to him; while if he partook of bonbons at dessert, there is no telling what number of poisonous pigments he might consume. Again, in his tea, if mixed or green, he would certainly not escape without the administration of a little Prussian blue, and it might be worse things; if he were a snuff-taker, he would be pretty sure to be putting up his nostrils, from time to time, small quantities of either some ferruginous earth, bichromate of potash, chromate of lead, or red lead: finally, if he indulged himself with a glass or so of grog before going to bed, he would incur the risk of having the coats of his stomach irritated with tincture of capsicum or essence of cayenne. If an invalid, *Injurious Substances actually detected in adulterated Articles of Consumption.*

Substances.	Articles.
Cocculus indicus.	Beer, rum.
Arsenite of copper, emerald green or Scheele's green.	Coloured sugar confectionery.
Sulphate of copper or blue vitriol, and acetate of copper or verdigris.	Pickles, bottled fruits and vegetables, tinned vegetables, preserves, dried and crystallised fruits, bread.
Carbonate of copper or verditer.	Coloured sugar confectionery and tea.
The three chromates of lead.	Custard powders, sugar confectionery, tea, and snuff.
Red oxide of lead.	Cayenne, curry powder, sugar confectionery.
Red ferruginous earths, as Venetian red, bole Armenian, red and yellow ochres, umber, &c.	Red sauces, as shrimp, lobster, anchovy, and tomato sauces; and in potted meats and fish, cocoa, chicory, coffee, anchovies, annatto, cheese, tea, snuff, &c.
Carbonate of lead.	Sugar confectionery.
Plumbago or black lead.	In certain black and lie teas.
Bisulphuret of mercury or cinnabar.	Cayenne, sugar confectionery.
Sulphate of iron.	Re-dried tea, and in beer.
Cayenne.	Gin, rum, ginger, mustard.
Gamboge.	Sugar confectionery.
Chromates of potash.	Tea and snuff.
The three false Brunswick greens, being mixtures of the chromates of lead and indigo, or Prussian blue.	Sugar confectionery.
Oxychlorides of copper or true Brunswick greens.	Ditto.
Orpiment or sulphuret of arsenicum.	Ditto.
Ferrocyanide of iron or Prussian blue.	Ditto.
Antwerp blue or Prussian blue and chalk.	Ditto.
Indigo.	Ditto.
Ultramarine.	Ditto.
Artificial ultramarine.	Ditto.
Hydrated sulphate of lime, mineral white, or plaster of Paris.	Flour, bread, sugar confectionery.
Alum.	Bread and flour.
Sulphuric acid.	Vinegar, gin.
Bronze powders or alloys of copper and zinc.	Sugar confectionery.

his condition would be still worse; for then, in all probability, he would be deprived of much of the benefit of the skill of his physician through the dilution and sophistication to which the remedies administered for his relief were subjected. This is no fanciful or exaggerated picture, but one based upon the results derived from the analysis of different articles as furnished to the consumer.

MORAL BEARINGS OF ADULTERATION.

The third and last aspect in which adulteration is to be considered is the moral.

It is impossible for a man to be guilty of adulteration and yet be an honest man. Can it even be said of the adulterator, be he a manufacturer or a roaster and grinder of chicory and coffee, or be he a retail tradesman who sophisticates the goods which he sells and mixes them with roasted corn or beans, Venetian red, &c., that he is guilty of a less offence than the common thief? The last takes but our property, while the former not only robs us of our substance, but sometimes our health as well.

But adulteration not only makes those who practise it dishonest, but other very serious evils often ensue: thus it begets a loss of confidence on the part of the buyer in those with whom he deals. In this way sometimes not only does the honest trader come to be looked upon with the same suspicion as the adulterating merchant or tradesman, but the *status* of the whole of that portion of the trading community engaged in the sale of articles of consumption is lowered, and it is looked upon with misgiving in all its transactions; lastly, the character of the whole nation for integrity in its dealings suffers in consequence of adulteration.

There is, then, scarcely an individual whose interests are not deeply concerned in the subject of adulteration. The interests of large public institutions of all kinds are vitally affected by adulteration, as our hospitals and other charitable establishments, workhouses, barracks, shipping, lunatic asylums, public schools, and similar institutions. Many of these establishments are supplied by contract with different articles of consumption, as milk, tea, sugar, coffee, cocoa, arrowroot, oatmeal, spices, &c. Now it often happens that the articles, and especially milk, oatmeal and arrowroot, supplied under these contracts, are adulterated, and this is frequently to be explained by the fact that these and other articles are sometimes purchased *under* market price, and consequently cannot possibly be genuine.

Taking into consideration, therefore, all the circumstances of the case, we believe it to be almost impossible to over-estimate the importance of the subject of adulteration, viewed either as a question of public health, of pecuniary loss to the consumer and the revenue, or as one of morality. To sum up, it is not too much to say that the question of adulteration is one which affects the health of thousands, and even the lives of many; that hundreds of thousands of pounds are annually lost to the consumer and the revenue by the practice of adulteration; and that by its prevalence the moral *status* of the commercial portion of the community of this country is lowered in the eyes of the world.

THE REMEDIES FOR ADULTERATION.

The means to be employed for the suppression of adulteration are of two kinds, viz., those which are used for the *discovery of* adulteration, and those for its *punishment.*

There are two principal means by which the discovery of adulteration is effected, *chemistry* and the *microscope.*

Chemistry has been long employed for the detection of adulteration, and it was upon this means of investigation that the earlier observers almost exclusively relied.

The application of the microscope to the detection of adulteration is comparatively new, and dates chiefly from the period at which the author's paper on the Adulteration of Coffee was communicated to the Botanical Society of London, that is from August, 1850.[1] This is certainly the most practical and important use which has ever been made of that instrument; for by its means hundreds of adulterations have been discovered, the detection of which is beyond the power of chemistry, and which had previously eluded all the efforts of science. The author claims to have been the first to employ on a large scale the microscope for the discovery of adulteration; on this point, however, the language of others may be quoted.

The 'Lancet,' in reviewing the author's work on the Adulteration of Food, writes, January, 1855: 'It is now unnecessary to say how completely Dr. Hassall dispelled the delusion as to the circumscription of science, and how he demonstrated that the microscope, wielded by the skilful naturalist and chemist, was able to unravel and to analyse the component structures of substances that bid defiance to the blowpipe and the test-tube alone. It is the great and original merit of Dr. Hassall to have applied the microscope to important uses in enquiries of this nature, and to have shown by it not only many things previously considered impossible to show, but many things not previously suspected to exist.'

The 'Quarterly Review,' in an article on the same subject, remarks: 'It is in the application of the microscope that consists Dr. Hassall's advantage over all previous investigators in the same field. The precision with which he is enabled to state the results of his labours leaves no appeal.'—March, 1855.

The 'Dublin Review' observes: 'The secret of his success has been that, in addition to chemical analyses, he has used the microscope in his enquiries; and his merit not only consists in the able manner in which he has employed the instrument, but in his being the first to use it practically and to such an extent for this purpose.

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[1] See 'Times,' August 5, 1850.

'The microscope,' writes the 'Times,'[1] referring to our labours, 'seems to have been the more effective instrument in the work. Less than five years ago it would, we are told, have been impossible to detect the presence of chicory in coffee. In fact, the opinion of three distinguished chemists was actually quoted in the House of Commons to that effect; whereas by the use of the microscope the differences of structure in these two substances can be promptly discerned.'

Lastly, the following remarks from the pen of a very able writer, Dr. Robert Barnes, may be quoted: 'The scientific originality of Dr. Hassall's labours in laying bare the health-destroying and fraudulent adulterations of food and drugs, is, if possible, still more meritorious; and it would be difficult to over-estimate the public importance of the results obtained. The means previously relied upon to check these adulterations were, the cumbrous and costly machinery of the Excise, and the subsidiary aid which chemistry could afford. The officers of the Excise were, for the most part, driven to seek for evidence by forcible entry and the seizure of articles found on suspected premises. When the art of the chemist failed, science was practically exhausted. So late as 1851, the then Chancellor of the Exchequer was able to quote in the House of Commons, as the deliberate opinion of three of the most distinguished chemists of the day, who had been specially requested to report upon the subject, '*that neither by chemistry nor by any other means could the admixture of chicory with coffee be detected.* How completely this foregone conclusion has been exploded by the labours of Dr. Hassall, as Analyst of the Sanitary Commission of the "Lancet," is notorious. There is now nothing in science more certain and precise than the discrimination, by means of the microscope, of the various forms of vegetable tissue, no matter to what extent they may be pulverised, mixed, or even roasted.

'The interest of Dr. Hassall's researches is universal. They have benefited the public revenue, every man in health or in sickness, and the physician who trusts in the properties of the agents, whether medicinal or dietetic, which he prescribes; and Parliament has been informed through them of new grounds and new principles of legislation. The great importance of the subject of the adulteration of food, drink, and drugs has already been recognised by Parliament, and this mainly through the labours of Dr. Hassall.'

THE APPLICATION OF THE MICROSCOPE TO THE DETECTION OF ADULTERATION.

The microscope is specially suited to the detection of organised structures or substances, as the several parts of animals and plants; it is with the latter that we chiefly have had to do in the course of the present work.

When we survey with our unaided vision any animal or plant, we detect a variety of evidences of organisation or structure; but there is in every part of every animal or vegetable production, an extraordinary amount of organisation, wholly invisible to the unarmed sight, and which is revealed only to the powers of the microscope. Now this minute and microscopical organisation is different in different parts of the same animal or plant, and different in different animals and plants, so that by means of these differences, rightly understood, the experienced microscopical observer is enabled to identify in many cases infinitely minute portions of animal or vegetable tissues, and to refer them to the parts or species to which they belong.

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[1] July 24, 1855.

Thus, by means of the microscope, one kind of root, stem, or leaf may generally be distinguished from another, one kind of starch or flour from another, one seed from another, and so on. In this way, the microscope becomes an invaluable and indispensable aid in the discovery of adulteration.

Applying the microscope to food, it appears that there is scarcely a vegetable article of consumption, which is not a liquid, which may not be distinguished by means of that instrument. Further, that all those adulterations of these articles which consist in the addition of other vegetable substances, and which constitute by far the majority of the adulterations practised, may likewise be discovered and discriminated by the same means.

The same remarks apply to all the vegetable drugs, whether roots, barks, seeds, or leaves. We are not acquainted with one such drug, which may not be thus distinguished.

The seeds even belonging to different species of the same genus may frequently be distinguished from each other by the microscope, a point in some cases of very great importance. A remarkable instance of this has fallen under our observation. The seeds of the different species of mustard, rape, &c. may all be distinguished under the microscope by differences in their organisation. To show the importance of the discrimination in some cases, the following instance may be cited. Some cattle were fed with rape cake, and died with symptoms of inflammation of the stomach and bowels. Nothing of a poisonous nature could be detected on analysis; but it was suspected that the cake might be adulterated with mustard husk, although even this point could not be clearly established by chemical research. Under these circumstances the cake was sent to the author for examination, who had but little difficulty in ascertaining that it was adulterated with mustard seed, which, from the large quantity consumed, was doubtless the cause of the fatal inflammation. Not only can the seeds of different plants of the same genus be frequently discriminated by the microscope, but in some cases those belonging even to mere *varieties* of species.

The microscope in some cases can even inform us of the processes or agents to which certain vegetable substances have been subjected.

Illustrations of this are afforded by the starches of wheat and barley; it can be determined by the microscope whether these are *raw, baked,* or *boiled,* or whether *malted* or *unmalted.* Illustrative figures will be found in the articles on BREAD and BEER.

Again it is not only when the articles are in a separate state that they can be thus distinguished; but even when mixed together in different proportions. We have succeeded in detecting in certain vegetable powders no less than nine different productions.

So great and manifest are the differences revealed by the microscope in various vegetable substances, that, with ordinary care and some amount of preliminary knowledge, the discrimination becomes a matter of the greatest ease and the most absolute certainty.

This will appear even from an examination of the numerous figures illustrative of the microscopical structure of different articles of food, and of the substances employed in their adulteration.

Further, wonderful to relate, the grinding and pulverisation, and even the charring, of many vegetable substances, does not so destroy their structure as to render their identification by the microscope impossible. Chicory and coffee may be thus roasted and pulverised, and yet each may be subsequently identified with the greatest ease, they being in fact but little changed, except in colour, and in the case of coffee by the dispersion of the droplets of oil visible in the cells of the unroasted berry.

Again, substances may be discovered by means of the microscope, even when introduced into articles for the purpose of adulteration in extremely minute quantities. The case of some mustard forwarded by a manufacturer to the 'Lancet' some time since furnished a remarkable illustration in point.

The mustard was stated to be genuine; but on examination with the microscope it was found to contain a small quantity of turmeric. The manufacturer, when informed of the fact, very candidly and properly acknowledged that this was the case, and stated that he had added '*two ounces of turmeric to fifty-six pounds* of seeds, not for the purpose of gain or adulteration, but simply to enliven the colour and make its appearance more acceptable;' that is, the quantity of turmeric present, and discovered by the microscope, consisted of only *one part in* 448 of the quantity examined.[1]

The last illustration—and a very striking and beautiful one it is, although not immediately connected with the subject of adulteration,—which we shall adduce in order to show the extraordinary character of the information furnished in some cases by the microscope, is supplied by honey.

Honey is the saccharine exudation from the nectaries of flowers: the bees in collecting it carry away some of the pollen of the flowers visited by them. Now this pollen consists of cells or vesicles, differing in size, form, and structure, according to the plants from which it is derived, certain plants being characterised by pollen granules of a certain configuration and organisation. By the pollen present in honey, therefore, the scientific microscopist acquainted with the characteristics of the pollen of different plants is enabled to decide in many instances upon the nature of the plants from which the honey has been procured, and whether it has been collected from the flowers of the field, the garden, the heath, or the mountain. (See article HONEY for figures in illustration.)

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[1] 'Food and its Adulterations,' p. 132.

There is still another use to which the microscope may be applied in the detection of adulteration; it may frequently be made to serve as an auxiliary to chemical researches: thus, for example, when we want to ascertain whether any substance contains starch, carbonates, phosphates, &c., it is often the quickest and most certain way to apply the reagents to a small quantity of the substance while this is under the field of vision of the microscope.

Chemistry is adapted particularly for the detection of the various chemical substances and salts used for adulteration: the microscope, on the other hand, as has been already stated, is specially suited to the detection of all organised structures and substances, whether animal or vegetable. Now it is precisely in this branch of investigation that chemistry fails to afford us any considerable aid.

Chemistry can tell us whether starch is present in any substance, but it is very seldom indeed that it can furnish us, as the microscope so constantly does, with the name of the plant from which the starch was derived: it can indeed also make us acquainted with the fact that woody fibre is contained in any particular article, but it cannot furnish us with the name of the tree or plant of which it formed a constituent.

Another great advantage of the microscope over chemistry is the greater speed with which results may be arrived at. Many chemical analyses occupy days, while most microscopical examinations may be made by the practised observer in the course of a few minutes. With the author's present knowledge, there are but few articles of which he could not examine readily 100 samples per week.

Before proceeding to the examination of any article with a view to discover whether it is adulterated or not, it is necessary to acquaint ourselves thoroughly with the appearance and structure of the article itself. If this be in the state of powder, as the different kinds of flour and arrowroot, nothing more is necessary than to place a very minute portion of it upon the glass slide, to add a drop or two of water, diffusing the powder evenly through it in a layer so thin that the light easily passes through it, to cover the object with a thin glass cover, and to place it in a proper position under the microscope for observation. If the vegetable substance be a solid one, as a root, stem, or seed, then it is necessary to make some thin sections of it, determining the structure from these. These sections are best prepared by means of a sharp and thin-backed razor: of these sections some should be longitudinal, others transverse, and others should embrace the surfaces of the object, both external and internal, where the latter exists. The examination is facilitated in some cases by tearing some of the sections in pieces with needles and also by examining them in glycerine in place of water, this rendering the structure more distinct. Lastly, where the article is one employed in the form of powder, it is necessary to prepare some of the genuine powder, and to make ourselves familiar with its structural characteristics.

Having progressed thus far in the examination of the article, we are in a position to scrutinise samples of it, with a view to the detection of adulteration. Knowing well the structures which are met with in the genuine article, we shall experience but little difficulty in determining whether the sample contains any foreign or extraneous vegetable substance, or consists entirely of the one article.

Having determined that it does contain such foreign substance, the next thing is to endeavour to ascertain the nature of this, and to refer it to the plant or substance to which it belongs. The facility with which this is done depends upon the extent of our acquaintance with other vegetable substances. If this be considerable, a glance is often sufficient to determine this point.

However, it is not requisite in all cases that we should possess a knowledge of the structure and appearances presented by any very great number of vegetable productions, since a few articles are constantly employed for adulteration in the case of very many and widely different articles, such as wheat flour, potato starch, sago powder, rice, &c.; and all that is necessary in such cases is that we should be able to recognise these substances when we meet with them.

Most vegetable substances are made up of certain structures and elements, as cellular tissue, woody fibre, vessels, starch granules, &c. In leaves we have stomata and often hair-like appendages, and in seeds there are two or more membranes. In endeavouring to discriminate between different vegetable substances, we must examine and compare most carefully these several tissues and structures, the one with the other. We must compare, both size and structure, the cellular tissue of one vegetable substance with that of another, and the same with the woody fibre, the vessels, the starch, &c.

Before proceeding to determine the minute structure of any vegetable substance by means of the microscope, we would strongly recommend the observer to study some work on Structural Botany, and thus to become acquainted with the characteristics of the principal tissues and elements which enter into the organisation of the several component parts of vegetables. He should acquaint himself with the characters and structure of cellular tissue, woody fibre, vascular tissue, sclerous tissue, of starch granules, with the general structure of roots and stems, leaves, flowers, including the pollen, and particularly with seeds. He will find a little preliminary study of vegetable anatomy facilitate greatly his subsequent and more special enquiries.

With a view to discover whether adulteration is practised upon any article, and the extent to which it is sophisticated, or whether adulteration prevails extensively in any town or locality, it is necessary that a considerable number of samples should be obtained and examined; that these should be procured without the knowledge of the vendor, and that the purchases should be made with such precautions, as to preclude the possibility of mistake; and also to allow of the verification of the samples to the satisfaction of a court of law.

In conducting the enquiries relative to adulteration, which were published for so many years in the 'Lancet,' under the title of 'The Analytical Sanitary Commission,' the following method was pursued:—

The purchases were made in the presence of witnesses, the author himself—for greater security, and knowing well the fearful responsibility which rested upon him—accompanying the purchasers on all occasions. Immediately that any article was thus obtained, the names of the sellers and of the buyers were placed upon it, the date of the purchase, and the price paid for it. Subsequently each sample was subjected to careful microscopical and chemical examination, the results of the analysis being written on the package and subsequently published from time to time in the 'Lancet,' together with the names and addresses of the merchants or traders from whom the purchases were made.

The publication of the several reports, which for a long time came out almost weekly, extended over a period of several years, and although the names of between two and three thousand traders were thus made known, in one case only were any legal proceedings resorted to, and even in this single instance the action was abandoned at an early date, without any acknowledgment being made of error having been committed.

We are disposed to rely more upon the regular publication of the names and addresses of those whose goods have been analysed for the suppression of adulteration than upon any other means, in consequence of the excellent effects which have undoubtedly resulted from their publication in the 'Lancet.' So great has been the effect of this publication, combined with the greater facilities which now exist for the detection of adulteration, and the disclosures made before Parliamentary Committees, that we are of opinion that not one-twentieth part of the adulteration now prevails, in the metropolis at least, as at the time when the reports of 'The Analytical Sanitary Commission' first appeared. In some articles the improvement is manifest to the eye alone, as in the red sauces, pickles, bottled fruits and vegetables, and coloured sugar confectionery.

The following remarks, in reference to the publication of the names of traders in the 'Lancet,' and the effect produced by the microscope, appeared in the 'Quarterly Review' for March, 1855, in a notice of the author's work, entitled 'Food and its Adulterations.'

'A gun suddenly fired into a rookery could not cause a greater commotion than did this publication of the names of dishonest tradesmen; nor does the daylight, when you lift a stone, startle ugly and loathsome things more quickly than the pencil of light, streaming through a quarter-inch lens, surprised in their native ugliness the thousand and one illegal substances which enter more or less into every description of food which it will pay to adulterate. Nay, to such a pitch of refinement has the art of fabrication of alimentary substances reached, that the very articles used to adulterate are themselves adulterated; and while one tradesman is picking the pockets of his customers, a still more cunning rogue is, unknown to himself, deep in his own.'

To summarise the preceding remarks, therefore, we would observe that for the discovery of adulteration we must have recourse to both chemistry and the microscope, and must examine a sufficient number of samples obtained by making purchases at shops in the ordinary way; but for its prevention when discovered recourse must be had to the punishment of the offenders.

Sale of Food and Drugs Act.

No punishment can be more effectual than the publication of the names and addresses of the adulterating tradesmen or merchants; but we must also put in operation the means which the legislature has now placed at our disposal for the suppression of adulteration. No less than three Acts have been passed dealing with the question of the adulteration of food and drugs. The first of these, 'An Act for Preventing the Adulteration of Articles of Food or Drink,' came into operation in 1860, and was the result of a Parliamentary enquiry, under the chairmanship of the late Mr. Scholefield, in 1855. This was a very inefficient measure, and was found to be quite useless; we do not remember to have ever heard of a prosecution under it.

The second Act, entitled 'An Act to Amend the Law for the Prevention of Adulteration of Food and Drink and of Drugs,' was passed in 1872. This was also a very inefficient Act, but one which, owing mainly to the interpretation put upon one of its clauses by the judges, who laid down the sound rule that the seller of an article ought to have a knowledge of its composition, and should know whether it was pure or adulterated, yet exerted a very beneficial effect. Under it many prosecutions and convictions took place, so that manufacturers and traders, finding that it really, in some cases at all events, reached them, grew very wroth, and banded themselves together in order to get the Act repealed. In this endeavour they have been but too successful. They obtained the appointment of another Parliamentary Committee, before whom a very one-sided enquiry took place, which has resulted in the passing of 'The Sale of Food and Drugs Act,' being 'An Act to Repeal the Adulteration of Food Acts, and to make better provision for the Sale of Food and Drugs in a Pure State.'

The Act in question will be found printed at the end of the volume, and we will now proceed to criticise its provisions.

Clause 3 provides that 'No person shall mix, colour, stain, or powder, or order or permit any other person to mix, colour, stain or powder any article of food with any ingredient or material so as to render the article injurious to health, with intent that the same may be sold in that state; and no person shall sell any such article so mixed, coloured, stained or powdered, under a penalty in each case not exceeding fifty pounds for the first offence; every offence after a conviction for a first offence shall be a misdemeanour, for which the person on conviction shall be imprisoned for a period not exceeding six months with hard labour.'

Here is a clause in which lawyers will delight, as it will be the fruitful cause of future litigation. There is no attempt made to define what constitutes injurious admixture. Everybody must form their own conclusions on the matter as best they may. These will often be erroneous, mistaken prosecutions will frequently be instituted at great cost and labour, and to the bitter disappointment of those concerned in them. It would have been quite easy to define what really constitutes injurious admixture. Will the coloration of green tea, or the presence of alum in bread, or the admixture of water with milk be deemed admixtures injurious to health under this clause? That the first adulteration—we beg pardon, the obnoxious word is foreign to this Act and does not once occur in it—that the first practice is in some cases injurious is unquestionable, and that the two latter are so, the one directly and the other indirectly, by depriving the article of its full nutritious properties, is equally certain, but these are just cases in which the opinions of even scientific men will be found to differ, and doubtless those of our magistrates and judges also. For ourselves, we should be very sorry to incur the responsibility of advising prosecutions under this clause in the cases named.

By clause 5 it is 'Provided, that no person shall be liable to be convicted under either of the two last foregoing sections of this Act, in respect to the sale of any article of food or of any drug, if he shows to the satisfaction of the Justice or Court before whom he is charged that he did not know of the article of food or drug sold by him being so mixed, coloured, stained or powdered, as in either of those sections mentioned, and that he could not with reasonable diligence have obtained that knowledge.'

By this clause, the principle laid down by our Judges in the cases brought before them under the Adulteration Act of 1872, that the vendor of any known and recognised article of food should be held to have a knowledge of its nature and composition is abolished, and the prosecutor must prove that the vendor actually knew at the time of the sale that the article was treated in one or other of the ways described in clause 3, or that he could with reasonable diligence have obtained that knowledge.

Again, who is to be the judge of what constitutes 'reasonable diligence?' Here again is one of those uncertain phrases in which lawyers delight, and which are the fruitful parents of endless legal proceedings.

By clause 6 it is enacted that 'No person shall sell to the prejudice of the purchaser any article of food or any drug which is not of the nature, substance and quality of the article demanded by such purchaser, under a penalty not exceeding twenty pounds. Provided that an offence shall not be deemed to be committed under this section in the following cases.'

Mark particularly the words 'to the prejudice of the purchaser.' It would appear that by this clause articles may be sold not of the substance, nature and quality of the article demanded by the purchaser, provided the seller can prove that the purchaser is not prejudiced thereby, so that it would appear possible that under this clause mixed mustard, coffee, or cocoa might be sold with impunity and without any acknowledgment of its being a mixture, if the seller could prove that the purchaser was not injured in pocket or in health by being supplied with the mixed article. Here, again, is another doubt. Who is to determine what will be held by our tribunals to be to the prejudice of the purchaser?

The exceptional cases referred to are:—

1. 'Where any matter or ingredient not injurious to health has been added to the food or drug, because the same is required for the production or preparation thereof, as an article of commerce in a state fit for carriage or consumption, and not fraudulently to increase the bulk, weight or measure of the food or drug, or conceal the inferior quality thereof.'

This exception, too, will make more work for the lawyers. Who is to determine what is required for the production or preparation of an article of commerce, in a state fit for carriage or consumption? The manufacturers of cocoa and mustard assert that sugar and starch in the one case, and wheat flour and turmeric in the other, constitute great improvements, and are not added fraudulently to increase the bulk, weight or measure. What will be the decision of our judges in such cases, who can tell?

4. 'Where the food or drug is unavoidably mixed with some extraneous matter in the process of collection or preparation.'

More doubts and difficulties. Who is to determine what constitutes 'unavoidable admixture?' Will the earthy matter found in such large quantities in pepper and tea be deemed an unavoidable admixture or not? That they will be held to be so by the dealers in those articles is unquestionable, and it will not be an easy matter to disprove their allegation, although the fact really is that such admixture of dirt may, with proper care and precautions in the collection and preparation of these articles, be completely avoided. Carefully-prepared tea and pepper do not contain any extraneous mineral matter whatever, or at all events an infinitesimal amount. This exemption offers a premium to dirt and uncleanliness, and under it certain kinds of adulteration will grow up and increase. Who is to distinguish whether the dirt found in the pepper and the tea has been purposely added, or is due to the exposure of the pepper berries and the tea leaves to dust and wind?

Again, under this clause, is the presence of copper in preserves and jams to be deemed an exception? The manufacturers will urge that they cannot prepare these articles in copper pans without their becoming more or less contaminated with copper. This is to some extent true, but the amount of contamination depends very much upon the care and skill with which the articles are made. But the consumer might maintain, on the other side, that vessels other than those made of copper should be employed in the preservation of such articles.

By clause 7 'No person shall sell any compounded article of food or compounded drug, which is not composed of ingredients in accordance with the demand of the purchaser, under a penalty not exceeding twenty pounds.'

This clause applies more particularly to the compounding of medicines, and it appears to have but little importance in relation to articles of food.

By clause 8 it is enacted 'That no person shall be guilty of any such offence as aforesaid in respect of the sale of an article of food or a drug mixed with any matter or ingredient not injurious to health and not intended fraudulently to increase its bulk, weight, or measure, or conceal its inferior quality, if at the time of delivering such article or drug he shall supply to the person receiving the same a notice by a label distinctly and legibly written or printed on or with the article or drug to the effect that the same is mixed.'

This clause is full of uncertainties. Can there be a reasonable doubt or question but that the large quantities of wheat flour met with in mustard and of sugar and starch in cocoa, and oftentimes of chicory in coffee, are added to augment the profit, and that the turmeric is sometimes employed to conceal the inferior quality of the mustard? Yet will it not be contended, and we fear successfully, that these additions are made in accordance with the usages of trade and in obedience to the demands of the public, so that under this clause, provided only a notice of its being a mixture be given, mustard, cocoa, and coffee will be sold as heretofore containing but very little of any of the substances under the names of which they are supplied to the public? These mixed articles will still be sold as mustard, cocoa, and coffee respectively. Then again, what protection does the notice or label afford to those who cannot read? that is to say, to many of the poor, who are the chief sufferers by the admixture and debasement of articles of consumption by the addition of inferior and comparatively valueless substances. Even when the purchaser can read, he will often fail to see, in the hurry of the purchase, whether the package bears the label or not, and if he does look for it he will frequently not find it, because it is concealed in some fold of the paper in which the article is enclosed.

Clause 9 provides that 'No person shall, with the intent that the same may be sold in its altered state without notice, abstract from an article of food any part of it, so as to effect injuriously its quality, substance or nature, and no person shall sell any article so altered without making disclosure of the alteration under a penalty in each case not exceeding twenty pounds.'

This clause is evidently framed with a view to meet the cases of the abstraction of the fatty matters from milk and cocoa, the Bill of 1872 not containing any provision for such cases.

This clause, which we were disposed to regard as one of considerable value, has already been rendered inoperative. In a case recently tried before one of our Metropolitan Magistrates, for the abstraction of a portion of the cream from milk, the defence set up was that the milk sold was poor in cream in consequence of the richer portions taken from the same pan having been previously sold, the fatty matter of course, in obedience to the law of gravity, having in part gradually risen to the surface. This defence was allowed to prevail, the prosecutor having to pay the costs.

The Act contains in addition special clauses relating to tea. One of these, clause 30, enacts that all tea imported into Great Britain or Ireland shall be subject to examination by persons to be appointed by the Commissioners of Customs with the approval of the Treasury, and if upon such examination the sample should 'be found to be mixed with other substances or exhausted tea, the same shall not be delivered unless with the sanction of the said Commissioners and on such terms and conditions as they shall see fit to direct, either for home consumption, or for use as ships' stores, or for exportation. But if on such inspection and analysis it shall appear that such tea is in the opinion of the analyst unfit for human food, the same shall be forfeited and destroyed or otherwise disposed of in such manner as the said Commissioners may direct.'

The examination of tea in bond is no doubt a step in the right direction, but supposing that notwithstanding such examination adulterated samples of tea are yet supplied to the public, the general provisions of the Sale of Food and Drugs Bill ought still to be available. Such a case as this is by no means improbable, and it is even quite conceivable that tea may be subjected to certain admixtures and additions after it has passed the Customs, and such cases would escape punishment altogether were it not that the other provisions of the Act could be brought to bear upon them.

Again, it will be noticed that, in the case of admixture being detected by the analyst appointed by the Commissioners of Customs, the rejection of the article is not to follow, except the tea be 'unfit for human food,' but the Commissioners are to be at liberty to allow of its being used either for home consumption, or as ships' stores or for exportation, so that if these gentlemen think fit the public will have no remedy, but will be obliged to drink those adulterated teas which have passed the Customs examination, or, if this is not allowed, they will find their way to our ships, our sailors being compelled to drink such teas, or lastly our colonies or dependencies may be made the recipients of the teas which the Commissioners consider to be too bad for home consumption.

We regard this as one of the weakest and worst clauses of the Bill. All teas which are mixed and debased should be rejected, and the Commissioners ought not to recognise and give their sanction to different degrees of debasement. Under this clause, if a tea be found to be mixed with lie tea, to contain sand and magnetic oxide of iron, or to be painted, it will still be in the power of the Commissioners to allow of its use in one or other of the ways above pointed out, because the analyst will in most cases be unable to declare that such teas, injured and debased as they are, are 'unfit for human food.'

With such provisions as these it is impossible to put a stop to the sophistication of tea, which now prevails to so great an extent and is practised in such a scandalous manner.

Clause 22 is as follows:—'The justices before whom any complaint may be made, or the court before whom any appeal may be heard under this Act may, upon the request of either party, in their discretion cause any article of food or drug to be sent to the Commissioners of Inland Revenue, who shall thereupon direct the chemical officers of their department at Somerset House to make the analysis, and give a certificate to such justices of the result of the analysis, and the expense of such analysis shall be paid by the complainant or the defendant as the justices may by order direct.'

It is not quite clear by this clause whether the plaintiff or defendant is at liberty in disputed cases to send a portion of the article in dispute to any independent analyst either may select, or whether it is incumbent upon them, if another chemical analysis be required, that it should *in all cases* be made in the laboratory of the Inland Revenue at Somerset House. If so, it appears to us that a monstrous injustice is perpetrated by the clause in question. Hitherto it has been the custom for each party to select their own analyst, and there are some chemists of high repute and unequalled experience in such cases who have hitherto been in the habit of being referred to. Now by this clause they are deprived of the just fruits of the labour expended in obtaining their reputation in this special department of analysis.

The Chemical Department of the Excise.

This brings us to make a few remarks on the fitness of the Excise Laboratory at Somerset House as a Court of Reference in such cases.

First, the Excise are not in an independent position; they are in Government employment and pay, and will necessarily regard things from a Governmental point of view, and with an eye to securing the Excise duties imposed.

Next, the chemists of the Excise have no enlarged or general experience of the question of adulteration at all. Their duties are limited to the examination of duty-paying articles only, and with all other articles they have nothing whatever to do. They take no notice of those adulterations which are simply frauds upon the consumer, or which are detrimental to the public health. They do not interfere with the adulteration of drugs unless they are liable to a duty, nor do they interdict the use of poisonous pigments in the colouring of sugar confectionery and other articles.

Again, they have afforded but few public proofs, so far as we are aware, of their competence for the duty imposed upon them. They may now be quite capable, but where have they given the evidence of special competence? It might have been expected that the Chemical Department of the Excise would have furnished the public with much valuable material and information as to the practice of adulteration; that they would have devised many new and simple processes for its detection, and that they would have from time to time put the public on their guard against certain adulterations coming more particularly under their notice.

Some years back, when the author first took up the subject of adulteration, it was scarcely possible to obtain an article which was not debased and adulterated, and whether it was a duty-paying article or not, adulteration was everywhere rife, and this in spite of the Excise, with its '4,000 inspectors and 70 chemists.' In fact, at that period they were notoriously incompetent, and they were wholly unacquainted with the use of the microscope in the detection of adulteration.

Doubtless they are now better informed, but having regard to their past history, it is certainly strange that this body should have been selected as a Court of Reference. At one time it was intended that the analyses made in the Laboratory at Somerset House should be final and binding on the litigants, but this last intention, we are glad to see, has been abandoned. We pointed out at the time, the absurdity of insisting that any analysis should be accepted as final, because however competent the analyst might be, mistakes might still be made, and no person could possibly be condemned on the report of one analyst, whoever he might be, if his statements could be proved to be erroneous by the testimony of other analysts.

Some idea of the manner in which the Excise performed its analytical duties at the time to which we have already referred, and how far it then protected the revenue from loss through adulteration, may be gathered from the following few particulars.

The article *tea* was then subject, as it still is, to considerable adulteration, while the extent to which the public were defrauded in *coffee* and *cocoa* is notorious; they were also largely defrauded in pepper, spirits, and tobacco, as is proved by the following results of analyses of those articles as supplied to the public, and as reported upon in the 'Lancet.'

Of numerous samples of black and white *pepper* analysed, fully one-half were adulterated with ground rice, pea-flour, wheat-flour, linseed meal, and mustard husk.

Of thirty-eight samples of *gin* examined, a very large proportion were adulterated, some of them being reduced in strength one-half, while seven of them contained cayenne pepper. The same was the case with *rum* and *brandy*.

Of forty-three different *snuffs* examined, nearly all were adulterated, the adulterating ingredients used being, for the most part, salt, alkalies, silica, red and yellow ochre, red lead, chromate of lead, and chromate of potash.

The Excise, then, at the period alluded to, had most signally failed in its principal duty—namely, the protection of the revenue against adulteration.

One reason why the chemists of the Inland Revenue failed, is that they did not sufficiently employ the resources of science for the discovery of adulteration: they relied too much upon the information of Excise inspectors, and too little upon science, upon the resources of chemistry, and more especially upon a knowledge of vegetable structure, as revealed to the competent observer by means of the microscope.

From not employing science enough, the Excise has, for the most part, in order to discover evidence of adulteration, been driven to adopt a system of espionage, and to the rude and inquisitorial proceeding of entering forcibly upon suspected premises, and of seizing any adulterated articles or substances employed in adulteration, and which, perchance, they might find in the course of their search. The method adopted by 'The Lancet' Commission was in striking contrast to this. It simply purchased the different articles as sold in the ordinary way of business, and applied to their analyses all the resources of science, especially the microscope. By this proceeding it was not necessary, as in the case of the Excise, to maintain an army of '4,000' inspectors, neither was it requisite to search the shop, warehouse, manufactory, or even the private dwelling of the occupants.

By the method we adopted we were led to the discovery of a variety of chemical adulterations of which the Excise possessed no knowledge; but it was in respect to the use of the microscope, in particular, as an instrument for the discovery of adulteration, that its knowledge was the most defective. Of this ignorance it has itself furnished a memorable and striking proof. In 1850 repeated remonstrances were addressed to the Government to prohibit the adulteration of coffee with chicory. The Government excused itself from interfering on the plea, publicly urged by the then Chancellor of the Exchequer, Sir Charles Wood, in the House of Commons, that, neither by chemistry nor by any other means was the adulteration of coffee with chicory to be detected. This statement was made on the strength of a report, procured at the instance of the Excise, from three of the most distinguished chemists of the day; the real fact at the same time being, that nothing is more easy or certain than the discovery of the adulteration in question by means of the microscope. Further, we have within the last few years brought to light, with the aid of the microscope, hundreds of adulterations, the existence of which was utterly unknown to the Excise.

We learn from the Report of the Select Committee on Adulteration, that, 'in addition to about 4,000 officers scattered over the country, the Board (of Excise) employs about sixty to seventy analytical chemists, whose numbers are recruited by students educated for the purpose at University College, to the number of fourteen in every year.' Why, here is a whole army of inspectors and analysts! With such huge machinery as this, the wonder is that adulteration should exist in any degree, much less that it should be so prevalent!

The only other point in connection with the Act which it is necessary to notice is, that the form of Certificate prescribed renders it necessary that the analyses of the articles submitted to the analyst should be quantitative. By the Act of 1872 he had simply to make a general or qualitative statement as to their composition. Of course a quantitative analysis is much more difficult, and requires greater skill and occupies longer time; hence analysts should be more liberally paid under this than the former Act.

As was the case with the Act of 1872, which dealt with the subject of adulteration, so it will be with the present Act. The efficacy of the former Act resulted in great part from the interpretation put upon it by the judges, and so it must be with the present measure, which is obviously full of uncertainties, and much will therefore depend upon the decision of the tribunals before whom prosecutions under it are heard. It is in our judgment a very feeble measure, framed to a large extent in the interest of traders and manufacturers, and not in those of the public. Taking it altogether, it is inferior to the Act of 1872, which it supersedes. It seems to us that the simplest and best course to have taken would have been to have modified that Act, and not to have abolished it altogether, and to have substituted for it something very much inferior.

A reluctance is expressed in some quarters to grapple with the giant evil of adulteration from the fear lest it should interfere with, and impose restrictions on, trade. This fear we believe to be groundless; and even if there were some foundation for it, yet it ought not to be allowed to prevail against what our consciences tell us to be right. Trade is one thing, debasing and poisoning our food another. Surely there is no necessary connection between the two; and if connected, the sooner the connection is severed the better on all grounds, and especially will it be to the advantage of trade itself. We maintain, however, that the connection which now exists is entirely unnatural, that it has sprung up under a careless and loose state of things, and that it is the duty of the State to interpose its authority for the prevention of adulteration.

Now it should be clearly understood that it is not necessary for the suppression of adulteration that restrictive measures should be resorted to, calculated to interfere with trade or to impede the liberty of the subject, beyond those already in existence; indeed, some of the restrictions now in force, and interference at present practised, might, under a better organisation, be discontinued.

Let us recall to mind the powers already conferred for the suppression of the adulteration of excisable articles. The Excise is at liberty to enter, by force, upon any premises where the adulteration of an exciseable article is suspected to be carried on, or where adulterated goods are supposed to be deposited; the adulterators or sellers of adulterated articles may be apprehended, punished by fines, which are sometimes very heavy, or imprisonment; all the adulterated articles may be confiscated, as well as the implements employed in their preparation. The Board may lock up a manufacturer's premises, taking the keys away, even when he is not practising adulteration, and it may control the processes of manufacture therein pursued. Here is interference with the freedom of trade and the liberty of the subject with a vengeance!

Again, magistrates or peace officers, by warrant, under the Bread Act, may search any premises and seize any adulterated flour or bread, search for any forbidden ingredient, inflict the penalties of fine and imprisonment; and lastly, they may publish the names of the offenders.

To prevent smuggling—an offence which, in its effects upon the revenue, is allied to adulteration—a large force, armed to the teeth, is stationed all around the coasts of these islands: it may seize the smuggler, and, if he resist, kill him; or it may take his contraband goods from him, and, on conviction, cast him into prison. Here, again, is interference with the liberty of the subject; and, remember, in smuggling, the revenue only is defrauded, and but little is thought of public health or morality.

Lastly, recall to mind the powers exercised, and properly so, in the cases of bad or diseased meat, and of short weights and measures, which, be it known, often go along with adulteration. In such cases there is the power of entering upon suspected premises, of seizing and confiscating the articles, and of punishing the wrongdoers by fine or imprisonment.

It may be inquired, how comes it that, with such powers of repression, adulteration so prevails? The answer is, that the laws in force respecting adulteration are partial only in their operation; that they relate only to certain articles; that they are for the most part but seldom enforced, and that some of them have even fallen into desuetude. What concerns everybody, what is everybody's business, becomes, in fact, according to the old adage, nobody's business.

The cries of 'freedom of trade' and 'the liberty of the subject,' in connection with adulteration, are in reality unmeaning terms, used as bugbears to frighten the timid and to throw the public off their guard.

In legislating upon the subject of adulteration, it should be remembered that the seller is frequently as much a party to adulteration as the actual adulterator. This is shown by the fact that he often buys articles at prices at which he knows it is impossible that they can be genuine. Again, it should be recollected that it is often the interest of the seller to screen the adulterating wholesale merchant or manufacturer, he, in many cases, being largely in his debt. In the course of the publication of the reports of 'The Lancet Sanitary Commission' we met with several cases in which the seller preferred to incur the risk consequent upon the publication of his name, rather than divulge the names of the parties by whom he was supplied. The seller, therefore, must not be let off too easily, especially when he attempts to screen the perpetrator of adulteration.

We cannot more appropriately conclude this Summary than in the following words, taken from a very able article on the author's book entitled 'Food and its Adulterations,' contained in the 'Quarterly Review':—'We have now shown enough to convince the public that the grossest fraud reigns throughout the British public commissariat . . . . . It remains to be seen whether the Government is able and willing to stay this gigantic evil and national dishonour.'

THE SALE OF FOOD AND DRUGS ACT.

A.D. 1875.

An Act to repeal the Adulteration of Food Acts, and to make better provision for the Sale of Food and Drugs in a pure state.

[11th August, 1875.]

WHEREAS it is desirable that the Acts now in force relating to the adulteration of food should be repealed, and that the law regarding the sale of food and drugs in a pure and genuine condition should be amended:

Be it therefore enacted by the Queen's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, as follows:—

Repeal of statutes.

1. From the commencement of this Act the statutes of the twenty-third and twenty-fourth Victoria, chapter eighty-four, of the thirty-first and thirty-second of Victoria, chapter one hundred and twenty-one, section twenty-four, of the thirty-third and thirty-fourth of Victoria, chapter twenty-six, section three, and of the thirty-fifth and thirty-sixth of Victoria, chapter seventy-four, shall be repealed, except in regard to any appointment made under them and not then determined, and in regard to any offence committed against them or any prosecution or other act commenced and not concluded or completed, and any payment of money then due in respect of any provision thereof.

Interpretation of words.

2. The term 'food' shall include every article used for food or drink by man, other than drugs or water:

The term 'drug' shall include medicine for internal or external use:

The term 'county' shall include every county, riding, and division, as well as every county of a city or town not being a borough:

The term 'justices' shall include any police and stipendiary magistrate invested with the powers of a justice of the peace in England, and any divisional justices in Ireland.

A.D. 1875.

Description of Offences.

Prohibition of the mixing of injurious ingredients, and of selling the same.

3. No person shall mix, colour, stain, or powder, or order or permit any other person to mix, colour, stain, or powder, any article of food with any ingredient or material so as to render the article injurious to health, with intent that the same may be sold in that state, and no person shall sell any such article so mixed, coloured, stained, or powdered, under a penalty in each case not exceeding fifty pounds for the first offence; every offence, after a conviction for a first offence, shall be a misdemeanour, for which the person, on conviction, shall be imprisoned for a period not exceeding six months with hard labour.

Prohibition of the mixing of drugs with injurious ingredients, and of selling the same.

4. No person shall, except for the purpose of compounding as hereinafter described, mix, colour, stain, or powder, or order or permit any other person to mix, colour, stain, or powder, any drug with any ingredient or material so as to affect injuriously the quality or potency of such drug, with intent that the same may be sold in that state, and no person shall sell any such drug so mixed, coloured, stained, or powdered, under the same penalty in each case respectively as in the preceding section for a first and subsequent offence.

Exemption in case of proof of absence of knowledge.

5. Provided that no person shall be liable to be convicted under either of the two last foregoing sections of this Act in respect of the sale of any article of food, or of any drug, if he shows to the satisfaction of the justice or court before whom he is charged that he did not know of the article of food or drug sold by him being so mixed, coloured, stained, or powdered as in either of those sections mentioned, and that he could not with reasonable diligence have obtained that knowledge.

Prohibition of the sale of articles of food and of drugs not of the proper nature, substance, and quality.

6. No person shall sell to the prejudice of the purchaser any article of food or any drug which is not of the nature, substance, and quality of the article demanded by such purchaser, under a penalty not exceeding twenty pounds; provided that an offence shall not be deemed to be committed under this section in the following cases; that is to say,

(1.) Where any matter or ingredient not injurious to health has been added to the food or drug because the same is required for the production or preparation thereof as an article of commerce, in a state fit for carriage or consumption, and not fraudulently to increase the bulk, weight, or measure of the food or drug, or conceal the inferior quality thereof;

(2.) Where the drug or food is a proprietary medicine, or is the subject of a patent in force, and is supplied in the state required by the specification of the patent;

(3.) Where the food or drug is compounded as in this Act mentioned;

(4.) Where the food or drug is unavoidably mixed with some extraneous matter in the process of collection or preparation.

Provision for the sale of compounded articles of food and compounded drugs.

7. No person shall sell any compound article of food or compounded drug which is not composed of ingredients in accordance with the demand of the purchaser, under a penalty not exceeding twenty pounds.

Protection from offences by giving of label.

8. Provided that no person shall be guilty of any such offence as aforesaid in respect of the sale of an article of food or a drug mixed with any matter or ingredient not injurious to health, and not intended fraudulently to increase its bulk, weight, or measure, or conceal its inferior quality, if at the time of delivering such article or drug he shall supply to the person receiving the same a notice, by a label distinctly and legibly written or printed on or with the article or drug, to the effect that the same is mixed.

Prohibition of the abstraction of any part of an article of food before sale, and selling without notice.

9. No person shall, with the intent that the same may be sold in its altered state without notice, abstract from an article of food any part of it so as to affect injuriously its quality, substance, or nature, and no person shall sell any article so altered without making disclosure of the alteration, under a penalty in each case not exceeding twenty pounds.

Appointment and Duties of Analysts, and Proceedings to obtain Analysis.

Appointment of analysts.

10. In the city of London and the liberties thereof the Commissioners of Sewers of the city of London and the liberties thereof, and in all other parts of the metropolis the vestries and district boards acting in execution of the Act for the better local management of the metropolis, the court of quarter sessions of every county, and the town council of every borough having a separate court of quarter sessions, or having under any general or local Act of Parliament or otherwise a separate police establishment, may, as soon as convenient after the passing of this Act, where no appointment has been hitherto made, and in all cases as and when vacancies in the office occur, or when required so to do by the Local Government Board, shall, for their respective city, districts, counties, or boroughs, appoint one or more persons possessing competent knowledge, skill, and experience, as analysts of all articles of food and drugs sold within the said city, metropolitan districts, counties, or boroughs, and shall pay to such analysts such remuneration as shall be mutually agreed upon, and may remove him or them as they shall deem proper; but such appointments and removals shall at all times be subject to the approval of the Local Government Board, who may require satisfactory proof of competency to be supplied to them, and may give their approval absolutely or with modifications as to the period of the appointment and removal, or otherwise: Provided, that no person shall hereafter be appointed an analyst for any place under this section who shall be engaged directly or indirectly in any trade or business connected with the sale of food or drugs in such place.

In Scotland the like powers shall be conferred and the like duties shall be imposed upon the commissioners of supply at their

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ordinary meetings for counties, and the commissioners or boards of police, or where there are no such commissioners or boards, upon the town councils for boroughs within their several jurisdictions; provided that one of Her Majesty's Principal Secretaries of State in Scotland shall be substituted for the Local Government Board of England.

In Ireland the like powers and duties shall be conferred and imposed respectively upon the grand jury of every county and town council of every borough; provided that the Local Government Board of Ireland shall be substituted for the Local Government Board of England.

Town council of a borough may engage the analyst of another borough or of the county.

11. The town council of any borough may agree that the analyst appointed by any neighbouring borough or for the county in which the borough is situated, shall act for their borough during such time as the said council shall think proper, and shall make due provision for the payment of his remuneration, and if such analyst shall consent, he shall during such time be the analyst for such borough for the purposes of this Act.

Power to purchaser of an article of food to have it analysed.

12. Any purchaser of an article of food or of a drug in any place being a district, county, city, or borough where there is any analyst appointed under this or any Act hereby repealed shall be entitled, on payment to such analyst of a sum not exceeding ten shillings and sixpence, or if there be no such analyst then acting for such place, to the analyst of another place, of such sum as may be agreed upon between such person and the analyst, to have such article analysed by such analyst, and to receive from him a certificate of the result of his analysis.

Officer named to obtain a sample of food or drug to submit to analysis.

13. Any medical officer of health, inspector of nuisances, or inspector of weights and measures, or any inspector of a market, or any police constable under the direction and at the cost of the local authority appointing such officer, inspector, or constable, or charged with the execution of this Act, may procure any sample of food or drugs, and if he suspect the same to have been sold to him contrary to any provision of this Act, shall submit the same to be analysed by the analyst of the district or place for which he acts, or if there be no such analyst then acting for such place, to the analyst of another place, and such analyst shall, upon receiving payment as is provided in the last section, with all convenient speed analyse the same and give a certificate to such officer, wherein he shall specify the result of the analysis.

Provision for dealing with the sample when purchased.

14. The person purchasing any article with the intention of submitting the same to analysis shall, after the purchase shall have been completed, forthwith notify to the seller or his agent selling the article his intention to have the same analysed by the public analyst, and shall offer to divide the article into three parts to be then and there separated, and each part to be marked and sealed or fastened up in such manner as its nature will permit, and shall, if required to do so, proceed accordingly, and shall deliver one of the parts to the seller or his agent.

He shall afterwards retain one of the said parts for future comparison and submit the third part, if he deems it right to have the article analysed, to the analyst.

Provision when samp is not divided.

15. If the seller or his agent do not accept the offer of the purchaser to divide the article purchased in his presence, the analyst receiving the article for analysis shall divide the same into two parts, and shall seal or fasten up one of those parts and shall cause it to be delivered, either upon receipt of the sample or when he supplies his certificate to the purchaser, who shall retain the same for production in case proceedings shall afterwards be taken in the matter.

Provision for sending article to the analyst through the post office.

16. If the analyst do not reside within two miles of the residence of the person requiring the article to be analysed, such article may be forwarded to the analyst through the post office as a registered letter, subject to any regulations which the Postmaster General may make in reference to the carrying and delivery of such article, and the charge for the postage of such article shall be deemed one of the charges of this Act or of the prosecution, as the case may be.

Person refusing to sell any article to any officer liable to penalty.

17. If any such officer, inspector, or constable, as above described, shall apply to purchase any article of food or any drug exposed to sale, or on sale by retail on any premises or in any shop or stores, and shall tender the price for the quantity which he shall require for the purpose of analysis, not being more than shall be reasonably requisite, and the person exposing the same for sale shall refuse to sell the same to such officer, inspector, or constable, such person shall be liable to a penalty not exceeding ten pounds.

Form of the certificate.

18. The certificate of the analysis shall be in the form set forth in the schedule hereto, or to the like effect.

Quarterly report of the analyst.

19. Every analyst appointed under any Act hereby repealed or this Act shall report quarterly to the authority appointing him the number of articles analysed by him under this Act during the foregoing quarter, and shall specify the result of each analysis and the sum paid to him in respect thereof, and such report shall be presented at the next meeting of the authority appointing such analyst, and every such authority shall annually transmit to the Local Government Board, at such time and in such form as the Board shall direct, a certified copy of such quarterly report.

Proceedings against Offenders.

Proceedings against offenders.

20. When the analyst having analysed any article shall have given his certificate of the result, from which it may appear that an offence against some one of the provisions of this Act has been committed, the person causing the analysis to be made may take proceedings for the recovery of the penalty herein imposed for such offence, before any justices in petty sessions assembled having jurisdiction in the place where the article or drug sold was actually delivered to the purchaser, in a summary manner.

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Every penalty imposed by this Act shall be recovered in England in the manner described by the eleventh and twelfth of Victoria, chapter forty-three. In Ireland such penalties and proceedings shall be recoverable, and may be taken with respect to the police district of Dublin metropolis, subject and according to the provisions of any Act regulating the powers and duties of justices of the peace for such district, or of the police of such district; and with respect to other parts of Ireland, before a justice or justices of the peace sitting in petty sessions, and subject and according to the provisions of 'The Petty Sessions (Ireland) Act, 1851,' and any Act amending the same.

Every penalty herein imposed may be reduced or mitigated according to the judgment of the justices.

Certificate of analyst primâ facie evidence for the prosecution, but analyst to be called if required. Defendant and his wife may be examined.

21. At the hearing of the information in such proceeding the production of the certificate of the analyst shall be sufficient evidence of the facts therein stated, unless the defendant shall require that the analyst shall be called as a witness, and the parts of the articles retained by the person who purchased the article shall be produced, and the defendant may, if he think fit, tender himself and his wife to be examined on his behalf, and he or she shall, if he so desire, be examined accordingly.

Power to justices to have articles of food and drugs analysed.

22. The justices before whom any complaint may be made, or the court before whom any appeal may be heard, under this Act may, upon the request of either party, in their discretion cause any article of food or drug to be sent to the Commissioners of Inland Revenue, who shall thereupon direct the chemical officers of their department at Somerset House to make the analysis, and give a certificate to such justices of the result of the analysis; and the expense of such analysis shall be paid by the complainant or the defendant as the justices may by order direct.

Appeal to Quarter Sessions.

23. Any person who has been convicted of any offence punishable by any Act hereby repealed or by this Act by any justices may appeal in England to the next general or quarter sessions of the peace which shall be held for the city, county, town, or place, wherein such conviction shall have been made, provided that such person enter into a recognizance within three days next after such conviction, with two sufficient sureties, conditioned to try such appeal, and to be forthcoming to abide the judgment and determination of the court at such general or quarter sessions, and to pay such costs as shall be by such court awarded; and the justices before whom such conviction shall be had are hereby empowered and required to take such recognizance; and the court at such general or quarter sessions are hereby required to hear and determine the matter of such appeal, and may award such costs to the party appealing or appealed against as they or he shall think proper.

In Ireland any person who has been convicted of any offence punishable by this Act may appeal to the next court of quarter sessions to be held in the same division of the county where the conviction shall be made by any justice or justices in any petty sessions district, or to the recorder at his next sessions where the conviction shall be made by the divisional justices in the police district of Dublin metropolis, or to the recorder of any corporate or borough town when the conviction shall be made by any justice or justices in such corporate or borough town (unless when any such sessions shall commence within ten days from the date of any such conviction, in which case, if the appellant sees fit, the appeal may be made to the next succeeding sessions to be held for such division or town), and it shall be lawful for such court of quarter sessions or recorder (as the case may be) to decide such appeal, if made in such form and manner and with such notices as are required by the said Petty Sessions Acts respectively hereinbefore mentioned as to appeals against orders made by justices at petty sessions, and all the provisions of the said Petty Sessions Acts respectively as to making appeals and as to executing the orders made on appeal, or the original orders where the appeals shall not be duly prosecuted, shall also apply to any appeal made under this Act.

In any prosecution defendant to prove that he is protected by exception or provision.

24. In any prosecution under this Act, where the fact of an article having been sold in a mixed state has been proved, if the defendant shall desire to rely upon any exception or provision contained in this Act, it shall be incumbent upon him to prove the same.

Defendant to be discharged if he prove that he bought the article in the same state as sold, and with a warranty.
No costs except on issues proved against him.

25. If the defendant in any prosecution under this Act prove to the satisfaction of the justices or court that he had purchased the article in question as the same in nature, substance, and quality as that demanded of him by the prosecutor, and with a written warranty to that effect, that he had no reason to believe at the time when he sold it that the article was otherwise, and that he sold it in the same state as when he purchased it, he shall be discharged from the prosecution, but shall be liable to pay the costs incurred by the prosecutor, unless he shall have given due notice to him that he will rely on the above defence.

Application of penalties.

26. Every penalty imposed and recovered under this Act shall be paid in the case of a prosecution by any officer, inspector, or constable of the authority who shall have appointed an analyst or agreed to the acting of an analyst within their district, to such officer, inspector, or constable, and shall be by him paid to the authority for whom he acts, and be applied towards the expenses of executing this Act, any Statute to the contrary notwithstanding; but in the case of any other prosecution the same shall be paid and applied in England according to the law regulating the application of penalties for offences punishable in a summary manner, and in Ireland in the manner directed by the Fines Act, Ireland, 1851, and the Acts amending the same.

Punishment for forging certificate or warranty;

27. Any person who shall forge, or shall utter, knowing it to be forged for the purposes of this Act, any certificate or any writing purporting to contain a warranty, shall be guilty of a misdemeanour

and be punishable on conviction by imprisonment for a term of not exceeding two years with hard labour;

for wilful misapplication of warranty;

Every person who shall wilfully apply to an article of food, or a drug, in any proceedings under this Act, a certificate or warranty given in relation to any other article or drug, shall be guilty of an offence under this Act, and be liable to a penalty not exceeding twenty pounds;

for false warranty;

Every person who shall give a false warranty in writing to any purchaser in respect of an article of food or a drug sold by him as principal or agent, shall be guilty of an offence under this Act, and be liable to a penalty not exceeding twenty pounds;

for false label.

And every person who shall wilfully give a label with any article sold by him which shall falsely describe the article sold, shall be guilty of an offence under this Act, and be liable to a penalty not exceeding twenty pounds.

Proceedings by indictment and contracts not to be affected.

28. Nothing in this Act contained shall affect the power of proceeding by indictment, or take away any other remedy against any offender under this Act, or in any way interfere with contracts and bargains between individuals, and the rights and remedies belonging thereto.

Provided that in any action brought by any person for a breach of contract on the sale of any article of food or of any drug, such person may recover alone or in addition to any other damages recoverable by him the amount of any penalty in which he may have been convicted under this Act, together with the costs paid by him upon such conviction and those incurred by him in and about his defence thereto, if he prove that the article or drug the subject of such conviction was sold to him as and for an article or drug of the same nature, substance, and quality as that which was demanded of him, and that he purchased it not knowing it to be otherwise, and afterwards sold it in the same state in which he purchased it; the defendant in such action being nevertheless at liberty to prove that the conviction was wrongful, or that the amount of costs awarded or claimed was unreasonable.

Expenses of executing the Act.

Expenses of executing Act.

29. The expenses of executing this Act shall be borne, in the city of London and the liberties thereof, by the consolidated rates raised by the Commissioners of Sewers of the city of London and the liberties thereof, and in the rest of the metropolis by any rates or funds applicable to the purposes of the Act for the better local management of the metropolis, and otherwise as regards England, in counties by the county rate, and in boroughs by the borough fund or rate;

And as regards Ireland, in counties by the grand jury cess, and in boroughs by the borough fund or rate; all such expenses payable in any county out of grand jury cess shall be paid by the treasurer of such county; and

The grand jury of any such county shall, at any assizes at which it is proved that any such expenses have been incurred or paid without previous application to presentment sessions, present to be raised off and paid by such county the moneys required to defray the same.

Special Provision as to Tea.

Tea to be examined by the Customs on importation.

30. From and after the first day of January one thousand eight hundred and seventy-six all tea imported as merchandise into and landed at any port in Great Britain or Ireland shall be subject to examination by persons to be appointed by the Commissioners of Customs, subject to the approval of the Treasury, for the inspection and analysis thereof, for which purpose samples may, when deemed necessary by such inspectors, be taken and with all convenient speed be examined by the analysts to be so appointed; and if upon such analysis the same shall be found to be mixed with other substances or exhausted tea, the same shall not be delivered unless with the sanction of the said commissioners, and on such terms and conditions as they shall see fit to direct, either for home consumption or for use as ships' stores or for exportation; but if on such inspection and analysis it shall appear that such tea is in the opinion of the analyst unfit for human food, the same shall be forfeited and destroyed or otherwise disposed of in such manner as the said commissioners may direct.

Interpretation of Act.

31. Tea to which the term 'exhausted' is applied in this Act shall mean and include any tea which has been deprived of its proper quality, strength, or virtue by steeping, infusion, decoction, or other means.

Provision for the liberty of a cinque port.

32. For the purposes of this Act every liberty of a cinque port not comprised within the jurisdiction of a borough shall be part of the county in which it is situated, and subject to the jurisdiction of the justices of such county.

Application of the Act to Scotland.

33. In the application of this Act to Scotland the following provisions shall have effect:

1. The term 'misdemeanour' shall mean 'a crime or offence:'
2. The term 'defendant' shall mean 'defender' and include 'respondent:'
3. The term 'information' shall include 'complaint:'
4. This Act shall be read and construed as if for the term 'justices,' wherever it occurs therein, the term 'sheriff' were substituted:
5. The term 'sheriff' shall include 'sheriff substitute:'
6. The term 'borough' shall mean any royal burgh and any burgh returning or contributing to return a member to Parliament:
7. The expenses of executing this Act shall be borne in Scotland, in counties, by the county general assessment, and in burghs, by the police assessment:
8. This Act shall be read and construed as if for the expression 'the Local Government Board,' wherever it occurs therein,

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the expression 'one of Her Majesty's Principal Secretaries of State' were substituted:

9. All penalties provided by this Act to be recovered in a summary manner shall be recovered before the sheriff of the county in the sheriff court, or at the option of the person seeking to recover the same in the police court, in any place where a sheriff officiates as a police magistrate under the provisions of 'The Summary Procedure Act, 1864,' or of the Police Act in force for the time in any place in which a sheriff officiates as aforesaid, and all the jurisdiction, powers, and authorities necessary for this purpose are hereby conferred on sheriffs:

Every such penalty may be recovered at the instance of the procurator fiscal of the jurisdiction, or of the person who caused the analysis to be made from which it appeared that an offence had been committed against some one of the provisions of this Act:

Every penalty imposed and recovered under this Act shall be paid to the clerk of the court, and by him shall be accounted for and paid to the treasurer of the county general assessment, or the police assessment of the burgh, as the sheriff shall direct:

10. Every penalty imposed by this Act may be reduced or mitigated according to the judgment of the sheriff:

11. It shall be competent to any person aggrieved by any conviction by a sheriff in any summary proceeding under this Act to appeal against the same to the next circuit court, or where there are no circuit courts to the High Court of Justiciary at Edinburgh, in the manner prescribed by such of the provisions of the Act of the twentieth year of the reign of King George the Second, chapter forty-three, and any Acts amending the same, as relate to appeals in matters criminal, and by and under the rules, limitations, conditions, and restrictions contained in the said provisions.

Interpretation of terms in application of Act to Ireland.

34. In the application of this Act to Ireland,—

The term 'borough' shall mean any borough subject to the Act of the session of the third and fourth years of the reign of Her present Majesty, chapter one hundred and eight, intituled 'An Act for the regulation of Municipal Corporations 'in Ireland:'

The term 'county' shall include a county of a city and a county of a town not being a borough:

The term 'assizes' shall, with respect to the county of Dublin, mean 'presenting term:'

The term 'treasurer of the county' shall include any person or persons or bank in any county performing duties analogous to those of the treasurer of the county in counties, and, with respect to the county of Dublin, it shall mean the finance committee:

The term 'police constable' shall mean, with respect to the police district of Dublin metropolis, constable of the Dublin Metropolitan Police, and with respect to any other part of Ireland, constable of the Royal Irish Constabulary.

Commencement of the Act.

35. This Act shall commence on the first day of October one thousand eight hundred and seventy-five.

Title of the Act.

36. This Act may be cited as 'The Sale of Food and Drugs Act, 1875.'

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SCHEDULE.

FORM OF CERTIFICATE.

To *

I, the undersigned, public analyst for the
do hereby certify that I received on the day of
18 , from † , a sample of
for analysis (which then weighed ‡), and have analysed
the same, and declare the result of my analysis to be as follows:—

I am of opinion that the same is a sample of genuine

or,

I am of opinion that the said sample contained the parts as under, or the per-centages of foreign ingredients as under.

Observations. §

As witness my hand this day of
A.B.,
at .

---

* Here insert the name of the person submitting the article for analysis.

† Here insert the name of the person delivering the sample.

‡ When the article cannot be conveniently weighed, this passage may be erased, or the blank may be left unfilled.

§ Here the analyst may insert at his discretion his opinion as to whether the mixture (if any) was for the purpose of rendering the article portable or palatable, or of preserving it, or of improving the appearance, or was unavoidable, and may state whether in excess of what is ordinary, or otherwise, and whether the ingredients or materials mixed are or are not injurious to health.

In the case of a certificate regarding milk, butter, or any article liable to decomposition, the analyst shall specially report whether any change had taken place in the constitution of the article that would interfere with the analysis.

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	Per Impl. Gall.	Per Octave.	Per Qr. Cask.	Per Hhd.	Per Butt.
	s. d.	£ *s. d.*	£ *s. d.*	£ *s.*	£ *s.*
Pale Sherry	9 6 ...	6 5 0 ...	12 0 0 ...	23 10 ...	46 0
Good Dinner Sherry ...	11 6 ...	8 0 0 ...	15 10 0 ...	30 10 ...	60 0
Fine Sherry	14 6 ...	9 15 0 ...	19 0 0 ...	37 10 ...	74 0
Superior Sherry	17 6 ...	11 10 0 ...	22 10 0 ...	44 10 ...	88 0
Choice Dessert Sherry ...	20 6 ...	13 5 0 ...	26 0 0 ...	51 0 ...	100 0
Old Sherry	23 6 ...	14 15 0 ...	29 0 0 ...	57 0 ...	112 0

Old Solera's ... ... £114 £125 £137 to £150 per Butt.

	Per Impl. Gall.	Per Octave.	Per Qr. Cask.	Per Hhd.	Per Butt.
	s. d.	£ *s. d.*	£ *s. d.*	£ *s.*	£ *s.*
Good Port	11 6 ...	8 15 0 ...	17 0 0 ...	33 10 ...	65 0
Fine Port	14 6 ...	10 5 0 ...	20 0 0 ...	39 10 ...	76 0
Fine Old Port	17 6 ...	12 0 0 ...	23 10 0 ...	46 10 ...	90 0
Choice Old Port	20 6 ...	13 15 0 ...	27 0 0 ...	53 0 ...	102 0

Curious Old Port ... ... £120 £135 £148 per Pipe.

Claret ... ... £14 £17 £20 £25 £30 £40 £50 £63 per Hhd.
Burgundy (Red and White) £20 £30 £35 £40 £50 £63 ,,
Old Pale Brandy ... 21*s.* 24*s.* 30*s.* 36*s.* per Imperial Gallon.
Old Irish and Scotch Whiskey ... ... 21*s.* per Imperial Gallon.

Messrs. HEDGES & BUTLER invite attention to their extensive stock of **CHOICE OLD PORT**, selected and bottled with the utmost care, and now in the highest state of perfection, embracing the famed vintages of 1840, 1847, 1858, 1861, and 1863—ranging in prices from 48*s.* to 120*s.* per dozen.

FOREIGN LIQUEURS OF EVERY DESCRIPTION.

☞ On receipt of a Post-Office Order, or reference, any quantity (with a Price List of all other WINES) will be forwarded immediately by

HEDGES & BUTLER,

LONDON: 155 REGENT ST., W. | BRIGHTON: 30 & 74 KING'S RD.

(ORIGINALLY ESTABLISHED A.D. 1667).

T. W. STAPLETON & CO.'S WINE TARIFF

(FOR THE PRESENT SEASON).

By Custom House Report, the largest Importers in England (not supplying the trade), duty paid in 1874 being 76,834 gallons.

Address 203 REGENT STREET, Corner of Conduit Street, W.

ESTABLISHED 1833.

1870 CLARETS.—Pure, sound Bordeaux, 14*s.* per dozen, or £6. 5*s.* per half hhd.; £12 per hhd., duty paid.

1868 VINTAGE EPERNAY CHAMPAGNE.—Magnificent in quality, brilliant in condition, ripe for drinking, 36*s.* per dozen quarts; 21*s.* pints.

1868 CREME DE BOUZY.—Pale, delicate, and dry, 42*s.* per dozen quarts, 24*s.* pints.

1868 L'EMPEREUR CHAMPAGNE, Première Qualité—a superb dry wine; the cream of the vintage; quarts, 62*s.*; pints, 34*s.* And all other brands.

1860 VINTAGE PORT.—Mature and fit for immediate use, 34*s.* per dozen.

1864 NATURAL SHERRY.—This elegant, pure, dry Xeres, 20*s.* per dozen. £5. 5*s.* per octave; £10. 10*s.* per quarter-cask; or the Star brand, 24*s.*, or £6. 6*s.* per octave, £12. 12*s.* per quarter-cask.

1861 MANZANILLAS.—Very delicate, at 30*s.*, or £15. 10*s.* per quarter-cask; and the driest and finest that can be shipped, 36*s.* per dozen. Specially recommended for invalids, being free from acidity.

T. W. STAPLETON & CO. invite attention to their choice selection of Old Brandies and superior mellow Whiskies, at 40*s.* per dozen.

IMPORTANT NOTICE.

MANZANILLA.—T. W. STAPLETON & CO., of 203 Regent Street, W., beg to call particular attention at this time, when Sherry Wine is so calumniated, to the following correspondence between Dr. Bartlett, the well-known and highly-talented analyst, and themselves.

No. 203 Regent Street, W., corner of Conduit Street,
H. C. Bartlett, Esq., Ph.D., F.C.S. July 11, 1874.

Dear Sir,—In answer to question 4,292, before the Select Committee of the House of Commons on the Adulteration of Food Act, you allude to Manzanilla, which you had tasted and pronounced excellent and pure wine; we shall be glad to know if the wine referred to was that which we supply to you, and if so, please let us have your complete analysis and report thereon.

We are, dear Sir, yours very obediently, STAPLETON & CO.

Laboratory, 7 South Square, Gray's Inn, London, W.C.
Messrs. Stapleton & Co., 203 Regent Street. July 18, 1874.

Dear Sirs,—In reply to your letter, I beg to state that I should not have mentioned the name of your firm before the Committee of the House of Commons if I had not been pressed to do so by Lord Barrington and another member.

These gentlemen were anxious to learn from whom I obtained the pure sherries, particulars of which were, by order of the Committee, laid before them. As there was no positive objection, I informed the Committee that I purchased the Manzanilla of you. The analysis proves it to be a light and clean dry wine, with admirable flavour and good scent. Its alcoholic strength is low, acidity very slight, and its extractive matter well developed. Such wine must be considered very wholesome, gently stimulant, and free from the common defects of the heavier Spanish wines. The dietetic qualities shown in the analysis on the other side will especially recommend this Manzanilla to all who have reason to be careful in their choice of sherry.

I am, faithfully yours,
(Signed) H. C. BARTLETT, Ph.D., F.C.S.

P.S.—Please send me the same quantity as before to my consulting room here.

T. W. STAPLETON & CO. think it unnecessary to do more than refer to the fact that Dr. Bartlett, among the numerous samples which came under his notice from some of the first firms in the trade, endorses his good opinion of their Manzanilla by using it at his own table, as mentioned before the Select Committee of the House of Commons.

Prices of this Wine, 30*s.* per dozen; £7. 15*s.* per octave; £15. 10*s.* per quarter-cask.

POWNCEBY'S
PURE WINES AND BRANDIES,

As analysed and pronounced 'THOROUGHLY GENUINE,' can be had in Small Quantities

At WHOLESALE PRICES.

The OLD PORTS from the WOOD

Are so thoroughly matured as to be superior in character to 'Bottled Wines' of a much higher price, and possess all the necessary qualifications that PORT WINE should contain to be beneficial in the highest degree.

The PALE FRENCH BRANDIES,

Being imported by ourselves and bonded many years in this country, an uniform age is guaranteed, besides a great saving being effected through importing in bulk. It frequently happens that Brandy known as 'Case Brandy' is often sold much too new, but bearing genuine labels &c. the Public are often thrown off their guard and naturally disappointed.

SUPERIOR OLD PORT for Invalids . . .	**16s.** per gall.	**36s.** per doz.
Do. do. . .	**18s.** ,,	**40s.** ,,
SHERRY, moderately dry, with excellent flavour and body . . . . from		**36s.** per doz.

PURE FRENCH BRANDY (Pale or Brown), **21s.** per gallon, up to **30s.** according to Vintage.

DR. HASSALL, in his Report says:—'The Pale French Brandies sold by Mr. Pownceby are a pure grape spirit matured by age, and valuable for medicinal or domestic purposes.'

Full Report and Price Current by post.

S. POWNCEBY & CO., 356 Oxford Street W.

PURE COGNAC BRANDY.

TRADE MARK

BOIZE'S LIQUEUR GRAPE 'BLUE LABEL' COGNAC BRANDY

(REGISTERED).

GEORGE BOIZE & CO. of Cognac, are the sole shippers of this celebrated old Brandy, which they have been advised to introduce by influential members of the medical profession, as a true remedy for the various complaints for which people in this country generally consume French Brandy.

The shippers having been aware for many years past of the inferior spirits offered to the consumer, under the names of French and British Brandy (so called British Brandy is not pure Brandy, not being produced from the juice of the grape), now bring this unequalled Liqueur before the notice of Connoisseurs and Invalids.

Report by ARTHUR HILL HASSALL, Esq., M.D.

'This Brandy possesses a fine and delicate aroma and flavour, which are in themselves characteristic of superior quality. Although it contains a large quantity of absolute alcohol it is yet soft to the palate, indicating that it has been kept for some years, and has thus become mellowed by age. Altogether it may be said of this Brandy, that it is very pure and of unusual excellence.'

The WINE TRADE REVIEW, *July* 1875.

'Apparently with a desire of founding a reputation upon quality rather than upon low prices, Messrs. GEO. BOIZE & Co. of Cognac are, we understand bottling for their "LIQUEUR GRAPE" only Brandies of 1848 vintage.'

The GROCER, *July* 3, 1875.

'A new brand has been introduced into the spirit market by Messrs. GEO. BOIZE & Co. of Cognac, under the title of the *Liqueur Grape Blue Label Cognac Brandy.* This firm is determined to found its reputation upon quality rather than upon low prices, and therefore is shipping only 1848 Brandy.'

BOIZE'S 'LIQUEUR GRAPE' BRANDY

Is to be had of all Wine Merchants and Grocers in the Kingdom, or Wholesale of

MESSRS. GEO. BOIZE & CO.,

61 MARK LANE, LONDON, E.C.

RAGGETT'S NOURISHING STOUT

AND

GOLDEN HOP PALE ALE.

'I have carefully analysed Raggett's well-known Nourishing Stout, as obtained from 21 Duke Street, St. James's, and find it to be a genuine, most wholesome, and highly nourishing beverage, less heavy and consequently more digestible than London Stout in general.'
(Signed) ARTHUR HILL HASSALL, M.D.

'The Golden Hop Pale Ale will no doubt become as popular as the well-known Nourishing Stout, it being scarcely possible to produce anything finer of its kind.' (Signed) ARTHUR HILL HASSALL, M.D.

CAUTION.—The Public are requested to note that the words 'RAGGETT late BLOCKEY' are upon the Labels of each Cask and Bottle of the genuine. This Caution is the more necessary as Brewers as well as Bottlers are adopting the word 'NOURISHING' upon Labels of their own in imitation of our well-known Trade Title.

SARSON'S VIRGIN VINEGAR.

MESSRS. SARSON & SON have appointed Special Agents in all Towns in the United Kingdom for the sale of their Virgin Vinegar in Pint and Quart Capsuled Bottles, the object being to ensure to the Public a Vinegar *pure as first drawn.* This Vinegar will be found very superior to the ordinary vinegar of commerce, the price is the same, namely,

5d. per Pint. 10d. per Quart.

OBSERVE.—Sold only in Capsuled Bottles bearing our Name and Trade Mark.

DAUKES & CO.

BOTTLED ALE & STOUT MERCHANTS,

FOR HOME USE AND EXPORTATION,

EXETER HALL VAULTS, STRAND, W.C.

GUINNESS'S EXTRA STOUT

AND

BASS'S & ALLSOPP'S

PALE AND BURTON ALES.

THE SAME AS SUPPLIED TO

INTERNATIONAL EXHIBITIONS

1871 TO 1874.

NUMBER ONE

ST. PAUL'S CHURCHYARD, E.C.

AND

OXFORD CIRCUS, W.

LONDON, December 1875.

We daily issue, gratis, a Price Current, which contains prices and descriptions of Black and Green Teas, Coffees, Cocoas and Chocolates, Arrowroots, Condiments, Farinaceous Food, Spices, &c. and the arrangements for the free delivery of orders &c.

We extract from it the following :—

'At the end of the year 1860, we took advantage of the passing of the Act—23rd and 24th Victoria, cap. 84—" for Preventing the Adulteration of Articles of Food or Drink," to organise a system of warranting all our goods.

'Another Act for the same purpose was passed in 1872—35th and 36th Vict., cap. 74.

'These Acts, and some others, have been repealed, and another Act passed, called "The Sale of Food and Drugs Act, 1875," but the system of warranty we adopted in 1860 appears to have anticipated so fully the principle and requirements of this Act that we continue to follow it, together with what improvements are possible.'

DAKIN & COMPANY,

TEA-MERCHANTS,

AND

PATENTEES FOR ROASTING COFFEE &c. IN SILVER CYLINDERS.

NUMBER ONE

ST. PAUL'S CHURCHYARD, E.C.

AND OXFORD CIRCUS, W.

TERMS, Net Cash.—The prices from the lowest to the highest are the most moderate possible for the qualities supplied.

DR. SIEGERT'S

ANGOSTURA BITTERS,

So justly celebrated for upwards of Forty Years for their exquisite Aromatic Flavour, were awarded 'Honourable Mention for Goodness of Quality' at the International Exhibition 1862, and Medal of Merit at the Vienna Exhibition 1873 (the highest distinction obtainable).

Used as ordinary Bitters with Wine or Spirits, or taken in Sugared Water, they are invaluable as an Appetiser and Tonic. They are most efficient in the cure of, and are also an excellent preservative against, Fever, Diarrhœa, Cholera, Liver Complaints, &c.

The following is a Copy of Dr. HASSALL'S Report on these Bitters.

'I have carefully analysed a sample of the well-known Angostura Bitters of Messrs. Siegert é hijos.

'I find that they consist of a mixture of certain bitter, aromatic, and carminative substances, together with alcohol, added as a preservative and solvent, and that they are altogether free from admixture with any dangerous or deleterious compound, as strychnine, for example, so commonly present in what are termed "pick-me-ups."

'These Bitters constitute, in fact, a very useful and wholesome Tonic when employed in suitable cases.

(Signed) 'ARTHUR HILL HASSALL, M.D.'

Author of 'Food and its Adulterations,' 'Adulterations Detected,' and late Editor of 'Food, Water, and Air.'

JOHNSON & CO.'S

CANTERBURY PALE ALE.

Brewed and Fermented by a special process for Exportation in Bottle to Hot Climates.

Dry Cooperage Casks, containing	4 doz. quarts,	8/-	per doz.
,, ,, ,,	8 ,, pints,	5/6	,,
Cases containing 1 doz. quarts	... ...	8/6	,,
,, ,, 2 ,, pints	... ...	5/9	,,

The Cases of 2 dozen pints are prepared for the Spanish Colonies, South America, West Indies, &c., and are an exact weight of 27 kilogrammes—21 of these cases go to the ton measurement.

The prices are for quantities over 20 dozen quarts or 40 dozen pints, in less quantity 4*d.* per dozen quarts and 2*d.* per dozen pints extra. JOHNSON & Co. take the Customs' drawback.

Free on board in the docks in London, Southampton, Dover, or Newhaven, less 5% for cash on delivery of bills of lading.

JOHNSON & CO.'S

CANTERBURY PALE ALE

(In Bulk).

Draught Ale, in	hogsheads,	£20	per ton of	4 hogsheads.
,, ,,	barrels ...	£22	,,	6 barrels.
,, ,,	kilderkins	£24	,,	12 kilderkins.

Free on board in the docks in London, Southampton, Dover, or Newhaven, less $2\frac{1}{2}$% for cash on delivery of bills of lading.

The season for exporting Draught Ale commences on November 1st, and terminates on March 30th for distant markets. European ports can be shipped to every month except August and September.

JOHNSON & CO., BREWERS, CANTERBURY;
AND 64 BASINGHALL STREET, LONDON, E.C.

Agencies in Sydney, Melbourne, Shanghai, Gibraltar, &c. &c.

THE

COMPRESSED TEA COMPANY

(LIMITED),

36 SOUTHWARK STREET, LONDON, S.E.

THE Leaf of the Tea Plant is a structure consisting entirely of cells; each cell is a closed sac, composed of an imperforate membrane, containing the soluble ingredients that form the infusion. The 'making' of Tea, from the leaves as imported, ruptures only a *portion* of these cells; but if the leaf be submitted to a very high pressure, the entire mass of cells is broken open, admitting the hot water *to all alike*, thus causing a considerable saving in the quantity required to be used, it being easy of demonstration that *one pound* of Compressed Tea produces a liquor about equal in quantity, quality, and strength to that produced by *two pounds* uncompressed.

Each Packet contains half-a-pound, which is sub-divided into half-ounces, thus enabling the Consumer to regulate his requirements with certainty.

The Company only selects Tea of undoubted purity, and the process it undergoes prevents the possibility of adulteration, in proof of which the Public is referred to the following extract from the Analytical Report of Dr. Arthur Hill Hassall, M.D.:—

'I have subjected samples both Compressed and Uncompressed of the Tea of the Compressed Tea Company (Limited) to full chemical analysis and microscopical examination, and find them to be of *good quality* and *perfectly genuine*.

'The Compressed Tea is more fragrant than the Uncompressed, and, owing to the rupture of many of their component cells, yields a larger proportion of the extractive matter and of the active constituents of the Tea than the Uncompressed.

'The compression of Tea into Cakes constitutes, in my opinion, a REAL and IMPORTANT improvement in the treatment of Tea.

(Signed) 'ARTHUR HILL HASSALL, M.D.'

Author of 'Food and its Adulterations,' 'Adulterations Detected,' late Editor of 'Food, Water, and Air.'

REPORT ON THE

BLACK AND GREEN TEAS

IMPORTED BY

MESSRS. HORNIMAN & CO.

LONDON.

THE ANALYTICAL SANITARY INSTITUTION,
2 Adelphi Terrace, Strand, London.

Nearly twenty-five years have passed away since I first drew attention to the fact, that all the China Green Teas and many of the Black sorts imported into this country were artificially coloured, painted, or faced with various organic and inorganic pigmentary matters. This practice I then denounced, and I have never lost an opportunity of continuing to do so since that period. In fact, from more extended knowledge and experience of the subject, I am of opinion that the practice is one which ought, in the interest of consumers, to be condemned in the strongest possible terms.

In 1859 I visited some of the Bonded Tea Warehouses containing consignments of Tea to the Messrs. Horniman, and I secured samples therefrom, which I subsequently submitted to analysis. I likewise then visited and inspected Messrs. Horniman's Warehouse in Wormwood Street, securing samples there in like manner, as well as from some of the appointed Agents of Messrs. Horniman, and I subjected the whole of the samples thus obtained to full examination and analysis.

I have again, after a lapse of fifteen years, instituted a similar inquiry. I have obtained a variety of samples of Black and Green Tea from Messrs. Horniman's stock in the Bonded Warehouses, from their London Warehouse, and from some of their Agents.

The whole of the Teas thus obtained have been subjected to full examination and analysis with the following results:—

1st. That the whole of the Teas examined were genuine, that is to say, they consisted wholly of the leaf of the Tea-plant—not a single foreign leaf being in any one of the samples.

2nd. That the whole of the Green Teas were entirely free from foreign colouring matters—the turmeric, the Prussian blue, and the silicate of magnesia, or soap, stone, &c.—with which the China Green Teas are so constantly faced.

3rd. That the whole of the Teas from Messrs. Horniman's stock in the Bonded Warehouses, from their London Warehouse, and from their appointed Agents, were of good quality as well as genuine, and that they furnished the full proportion of extractive matters characteristic of good Tea.

(Signed) **ARTHUR HILL HASSALL, M.D.**

Author of the Reports of the Analytical Sanitary Commisssion of the 'Lancet,' now published under the title of 'Food and Its Adulterations;' of 'Adulterations Detected;' and Editor of 'Food, Water, and Air,' &c.

SOLD IN PACKETS BY 3,538 AGENTS, CHEMISTS, CONFECTIONERS, &c.

NINE EXHIBITION MEDALS AWARDED TO J. S. FRY & SONS.

FRY'S CARACAS COCOA.

This Cocoa owes its Delicious Flavour to the use of the celebrated Caracas Nut, combined with other choice descriptions, specially selected for their peculiar excellence, and invigorating qualities.

'Caracas Cocoa has ever been considered the best of all that is produced upon the American soil.'—R. T. C. MIDDLETON, Consul-General, Caracas.—*Journal of Applied Science.*

'No more delicious, refreshing, nourishing, and wholesome beverage has ever been manufactured.'—*Morning Post.*

'A packet can easily be obtained, and its delicate flavour and fine aroma ensure its adoption as a beverage for breakfast or supper.'—*Standard,*

'The Caracas Cocoa of such choice quality.'—*Food, Water, and Air*, edited by Dr. HASSALL.

'A most delicious and valuable article.'—*Standard.*

FRY'S EXTRACT OF COCOA.

In 6d. Packets, 1s. and 2s. Tins.

A perfectly pure and delicious beverage, prepared exclusively from choice Cocoa Nibs deprived of the superfluous oil, and of great value to invalids who wish to avoid rich articles of diet. Purchasers of this class of Cocoa should ask for 'Fry's Extract of Cocoa.'

'The "Extract of Cocoa," which really consists of Cocoa Nibs deprived of superfluous oil, than which, if properly prepared, there is no nicer or more wholesome preparation of Cocoa.'—*Food, Water, and Air*, Dr. HASSALL.

FRY'S CARACAS CHOCOLATE.

In ½ lb. and ¼ lb. Cakes. Yellow Wrappers.

This really excellent and delicious Chocolate is also prepared with Caracas and other choice Cocoas, long adopted in the manufacture of the finest Chocolates of Europe. It is offered at a very moderate price, and the Manufacturers confidently challenge for it, competition with any other Chocolate, whether of English or Foreign Manufacture, at a similar price.

'Fry's Caracas Cocoa and Chocolate fulfil every possible requirement for convenience, for flavour, and for purity.'—*Court Circular.*

SCHWEITZER'S
COCOATINA.

ANTI-DYSPEPTIC COCOA OR CHOCOLATE POWDER.

GUARANTEED PURE SOLUBLE COCOA, WITHOUT ADMIXTURE.

STRONGLY RECOMMENDED BY THE FACULTY FOR FAMILY USE.

Cocoatina is the highest class of Soluble Cocoa or Chocolate in a concentrated form, consisting solely of the finest Cocoa Beans without Sugar, the excess of fat being extracted by a delicate mechanical process, without prejudice to quality or flavour.

THE FACULTY pronounce it 'the most nutritious, perfectly digestible beverage for Breakfast, Luncheon, or Supper, suitable to the healthy as well as to the weak.'

HIGHLY RECOMMENDED BY THE ENTIRE MEDICAL PRESS.

COCOATINA *will bear the Strictest Chemical Investigation.*

It is prescribed, with great success, for delicate Females and Children, when all other food is rejected; and celebrated for its restorative properties in cases of Debility and Imperfect Digestion.

Being absolutely free from Sugar (the *excess* of Fat), or any admixture, it keeps better in all Climates, and is four times the strength of Cocoas *thickened* yet *weakened* with Arrowroot, Starch, &c., *and in reality cheaper;* one teaspoonful being sufficient for a cup of Cocoa (*the cost of which is less than a halfpenny*), and two or more for a cup of Chocolate.

Cocoatina *à la Vanille is the most delicate, digestible, and cheapest Vanilla Chocolate, and is taken when richer Chocolates are prohibited.*

Dr. Arthur Hill Hassall says in *Food, Water, and Air* :—

'This preparation has more than once been brought under our notice, and always with the same result. It consists entirely of the powder [of a marvellous degree of fineness] of the very best qualities of the Cocoa Bean, without the smallest admixture of Sugar, Starch, or Arrowroot. It is consequently full of aroma and flavour, and is lighter and more digestible than are most Cocoas, *thickened* and *yet weakened* by admixture with large quantities of farinaceous matter.'

DIRECTIONS FOR USE ON THE LABEL OF EACH PACKET.

Retailed in Air-tight Tin Packets only, at 1s. 6*d*., 3*s*., 5*s*. 6*d*., *&c., by Chemists, Grocers, &c.*

SOLE PROPRIETORS,

H. SCHWEITZER & CO., 10 Adam St., London, W.C.

BARRY & CO.

CHICORY, COCOA, AND MUSTARD MANUFACTURERS,

29 & 30 ROPEMAKER STREET,

AND

6 TYPE STREET, FINSBURY, LONDON, E.C.

Bonded Export Warehouse:

GRAND SURREY DOCKS, LONDON, S.E.

BARRY & CO. beg to call special attention to the following Leading Articles of their Manufacture:—

PREPARED COCOA in ¼lb. packets, 1s. per lb. **PEARL COCOA,** ¼lb. packet, 8d. per lb. Also **HOMŒOPATHIC COCOA,** in tin-foil packets. **ROCK COCOA,** and **GENUINE FLAKE COCOA. PURE TRINIDAD COCOA NIBS,** guaranteed perfectly free from any colouring matter.

And every other description of Cocoa and Chocolate.

BARRY & CO.'S GENUINE MUSTARD.

The Extra Strong and Double Superfine qualities are prepared from the choicest Brown and White Mustard Seed, combining great pungency with delicate flavour.

BARRY & CO. guarantee every article of their manufacture to be perfectly free from any injurious ingredients.

THE 'WARRANTED' PICKLES.

DR. HASSALL'S REPORT.—'These Pickles have been subjected by me to carefu Analysis, and with the most satisfactory results.

They were found to be free from the smallest trace of Copper and of uncombined Sulphuric Acid.

'23rd November, 1870. (Signed) 'ARTHUR HILL HASSALL, M.D.'

PREPARED ONLY BY

GEORGE WHYBROW,

48 & 49 WELLCLOSE SQUARE, and 10 & 12 PELL STREET, LONDON, E.

SELECTED VEGETABLES. PUREST GRAIN VINEGAR.

ESTABLISHED 40 YEARS.

CADBURY'S COCOA ESSENCE,

GUARANTEED PURE AND SOLUBLE,

Is now taken by thousands as a light and invigorating Beverage who could not before use 'Prepared Cocoa,' owing to its being too thick and heavy. It is three times the strength of the best 'Homœopathic Cocoas,' to which starch and sugar is added.

CADBURY'S MEXICAN CHOCOLATE

(In Blue Wrapper) Consists solely of the Finest Cocoa and White Sugar.

EDWARD PINK'S PICKLES

ARE THE BEST.

ALSO

JAMS, JELLIES, AND MARMALADE,

OF VERY SUPERIOR QUALITY.

They can be obtained of Grocers or Oilmen throughout the United Kingdom.

ANALYTICAL REPORT BY DR. HASSALL.

THE ANALYTICAL SANITARY INSTITUTION.
14 JOHN STREET, ADELPHI, LONDON.
5th February 1874.

I have carefully analysed two samples of the Pickles prepared by MR. E. PINK. They are made with good strong vinegar, entirely free from uncombined sulphuric acid. The vegetables employed are of good quality, and carefully selected. A minute search was made for copper, but not a trace of that metal, so frequently present in Pickles, could be detected.

ARTHUR HILL HASSALL, M.D.
Author of 'Food and its Adulterations,' 'Adulterations Detected and late Editor of 'Food, Water, and Air.'

EDWARD PINK'S MARMALADE

IS THE BEST.

Prepared by Steam Machinery of the Finest Seville Oranges and Refined Sugar.

ALSO

JAMS, JELLIES, PICKLES, & SAUCES

OF VERY SUPERIOR QUALITY.

They can be obtained of Grocers or Oilmen throughout the United Kingdom.

ANALYTICAL REPORT BY DR. HASSALL.

The Analytical Sanitary Institution,
2 Adelphi Terrace, Strand, London.
5th February 1874.

I have recently visited the Manufactory of Mr. EDWARD PINK, and have made myself thoroughly acquainted with the process of Manufacture of Marmalade therein pursued. I find that much care is bestowed upon its preparation, it being made by the aid of appropriate and ingenious machinery on a large scale, and in an incredibly short space of time. I find, further, that the Marmalade is prepared (with the exception of a *small* quantity of Apple Jelly, which is used to soften and mellow the strong bitter of the Orange) entirely from the 'Seville Orange,' and that it is free from the smallest trace of copper and other impurities. Of the wholesomeness of Orange Marmalade when thus prepared, nothing need be said.

ARTHUR HILL HASSALL, M.D.

PURE BLACK TEA, PURE COFFEE,

PURE UNCOLOURED GREEN TEA.

THE BEST AND CHEAPEST BLACK TEA,

STRONG *to* FINE BLACK TEA,

1s. 4d., 1s. 6d., 2s., 2s. 3d., and 2s. 6d. per Pound.

40*s*. worth sent carriage free to any railway station or market town in England or Wales, on receipt of 40*s*., by

PHILLIPS & CO., Tea Merchants,

8 KING WILLIAM STREET, E.C.

PRIME COFFEE, 1s. 4d., 1s. 6d., 1s. 8d.

A Price and Store List containing Dr. Hassall's last report on Phillips and Company's Teas, is sent post free on application.

CROSSE & BLACKWELL,

PURVEYORS TO THE QUEEN,

SOHO SQUARE, LONDON,

Direct attention to the following articles of their Manufacture, which always bear their Name and Address on the Labels.

PURE PICKLES IN MALT VINEGAR.

CAPT. WHITE'S ORIENTAL PICKLES, an exquisite compound of sweets and sours.

PURE MALT VINEGAR of uniform strength and flavour, in Imperial pint and quart bottles.

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POTTED MEATS and FISH in fancy tins and jars

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JAMS, JELLIES, and ORANGE MARMALADE made from fresh Fruit and with refined Sugar only.

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FLAVOURING ESSENCES, distilled from the Fresh Fruits and Spices, Orange, Lemon, Vanilla, Almond, Ginger, Mace, &c.

CROSSE & BLACKWELL'S *Genuine Manufactures always bear their Name and Address on the Labels, and may be obtained of Grocers, Chemists, and Italian Warehousemen throughout the World.*

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CLEAR TURTLE and other SOUPS. BEEF TEA and ESSENCE of BEEF.
ESSENCE of CHICKEN and CHICKEN BROTH. CALVES'-FEET JELLIES.

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A Single Trial Solicited from those who have not yet tried these splendid preparations.

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THE BEST IN THE WORLD.

The cheapest because the best, and indispensable to every household, and an inestimable boon to housewives. Makes delicious Puddings without eggs, Pastry without butter, and beautiful light Bread without yeast. Sold by Grocers, Oilmen, Chemists, &c., in 1*d*. Packets, 6*d*., 1*s*., 1*s*. 6*d*., and 2*s*. Tins.

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The most Delicious Sauce in the World.

This cheap and excellent Sauce makes the plainest viands palatable, and the daintiest dishes more delicious. To Chops, Steaks, Fish, &c., it is incomparable. Sold by Grocers, Oilmen, Chemists, &c. in Bottles, 6*d*., 1*s*., and 2*s*. 6*d*. each.

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The best, cheapest, and most agreeable tonic yet introduced. The best remedy known for Indigestion, Loss of Appetite, General Debility, &c. &c. Restores delicate invalids to health and vigour. Sold by Chemists, Grocers, &c., at 1*s*., 1*s*. 1½*d*., 2*s*., and 2*s*. 3*d*. each Bottle.

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May be obtained from all the leading Grocers in

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AND NEARLY EVERY TOWN IN THE KINGDOM.

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HARVEST'S GENUINE ESSENCE OF ANCHOVIES,

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BRIDGE ROAD,

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HARDS'

FARINACEOUS FOOD

Has been extensively used by the Public for upward of 50 YEARS,

And well-known as superior to all descriptions of Food

FOR INFANTS AND INVALIDS.

JONATHAN PEREIRA, M.D.

AND

ARTHUR HILL HASSALL, M.D.

Give the following Reports:—

'I have carefully examined and repeatedly prescribed "Hards' Farinaceous Food" (see Pereira's "Treatise on Food and Diet," pages 309 and 473, &c.) which is prepared from the most nutritious of the Cereal grains. It combines both nitrogenised and non-nitrogenised alimentary principles, and for a very valuable Food for Children and Invalids.

'**JONATHAN PEREIRA, M.D., F.R.S.**

'Physician to the London Hospital.

'47 Finsbury Square,
'July 1, 1843.'

'I have recently examined with much care, both microscopically and chemically, the article known as "Hards' Farinaceous Food," which has now been before the public for so many years.

'I find it to be carefully prepared, to be perfectly genuine, and highly nutritious; those results being corroborated by many previous examinations of the article made at various times, during the past few years, and entirely without the knowledge of the proprietor.

'It possesses certain important advantages over the majority of Food sold for Infants and Invalids, it being more digestible, and in the large proportion of gluten which it contains, and which is the blood and flesh-producing constituent of the Food. The greater number of Farinaceous Foods sold, consist wholly of arrowroot or starch, which do not contain gluten or nitrogen in any form, and such articles are therefore wholly destitute of any principle from which blood and flesh can be formed, so that infants fed exclusively upon them would be in danger of dying from actual starvation. This fact cannot be too generally impressed upon Mothers, and all persons engaged in the rearing of Children.

'**ARTHUR HILL HASSALL, M.D.**

'Analyst of the Lancet Sanitary Commission.
'Author of "Food and its Adulterations," &c.

'Wimpole Street, Cavendish Square, W.'

'Feb. 1, 1860.'

Sold in all parts of the world by Chemists, Patent Medicine Vendors, and Italian Warehousemen, in 1*s. and* 2*s. Packets, and Tin Cases* 7*s.* 6*d. each; and*

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ROYAL VICTORIA MILL, DARTFORD,

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HEALTHY CHILDHOOD PROMOTES ROBUST MANHOOD.
NEAVE'S FARINA-CEOUS FOOD
INFANTS INVALIDS
TRADE MARK.

NEAVE'S FOOD

FOR

INFANTS AND INVALIDS,

Is a preparation from the finest description of Cereal Grains.

It is rich in albumenoids, starch, phosphates, cellulose, &c., and is highly recommended by medical men and others, who have brought up their own children upon it.

Dr. C. A. CAMERON, of Dublin, says of this food—

'This is an excellent Food, admirably adapted to the wants of infants and young persons. It contains a small though sufficient quantity of very fine bran, which being rich in phosphates and potash, is of the greatest utility in supplying the bone-forming and other indispensable elements of food. The albumenoids, or flesh-forming ingredients of this food are very abundant; and its large percentages of fat-producing materials will effectually contribute to the maintenance of the heat and work of the animal mechanism. Although peculiarly adapted to the wants of the young, this food may be used with advantage by persons of all ages.'

The late Dr. LANKESTER, F.R.S., Coroner for Middlesex, said—

'I have examined specimens of NEAVE'S FARINACEOUS FOOD for Infants and Invalids, and find it to consist of carefully prepared flour from cereal grains, and to be free from any impurities or substances of an injurious character. I have also tested dietetically the Food prepared according to the directions for use, and have found it to be a very agreeable article of diet. I have pleasure in recommending it, especially for children, as containing, in due proportion, the flesh-forming and heat-giving elements of food.'

From Dr. HASSALL, Author of 'Food and its Adulterations,' and other Works.

'The chemical analysis of a sample of NEAVE'S FOOD, recently made by me, furnishes the following results:—

Moisture..	5·77 per cent.
Nitrogen, 3·07 per cent., equal to gluten (the flesh-forming element)	18·98 ,,
Fatty Matter	9·39 ,,
Starch, gum, cellulose, &c.	71·51 ,,
Saline matter, chiefly phosphates, ..	1·35 ,,

'These results are remarkable in several respects; as for the small quantity of moisture contained in the article, the large amount of the flesh-forming material, of fatty matter, and of phosphates. Further they demonstrate that this Food is of a highly nourishing character, and admirably suited for the sustenance of Infant Children and of Invalids.'

Many other medical and private testimonials might be added, but they are unnecessary, as a trial will be a most satisfactory proof of excellence.

Neave's Food is sold in Shilling Tins by Chemists and Grocers at home and abroad.

J. R. NEAVE & CO., MANUFACTURERS, FORDINGBRIDGE.

SILVER MEDAL,
PARIS EXHIBITION, 1867.

TRADE MARK. TRADE MARK.

SAVORY & MOORE'S

Best Food for Infants,

AS SUPPLIED TO THE ROYAL NURSERIES.
Specially prepared on the principles recommended by
BARON LIEBIG.

"The Infant Prince has taken this Food for some months past, and thrives upon it as a Prince should."—Dr. Richardson.

MEDICAL AND SCIENTIFIC TESTIMONY.

"In the preparation of an infant's food, required at all hours of the day and night, *the saving of time and trouble is of the utmost importance.* 'The Infants' Food of Messrs. SAVORY & MOORE is a REAL IMPROVEMENT' on the ordinary preparations."—THE LANCET.

"We can tell from our own experience that this Food once tried, becomes a favorite in the nursery, and that children thrive well on it."—MEDICAL TIMES AND GAZETTE.

"SAVORY & MOORE have saved mothers and nurses much time and trouble by supplying them with a FOOD FOR INFANTS in a very convenient form, and of a composition that can always be relied on. It can be taken when nothing else can. It has been analysed and examined by Drs. LANKESTER and RICHARDSON AND HAS BEEN PRACTICALLY TESTED ON NO LESS A PERSON THAN A ROYAL PRINCE."—THE MEDICAL PRESS.

"Dr. HASSALL, reports, "This Food is eminently adapted to the food of infants, being highly nourishing, and what is of the greatest consequence, of easy digestibility."

Dr. T. HERBERT BARKER, F.R.S., *Author of "Right Foods for Infants and Children."*

"The LIEBIG'S FOOD of Messrs. SAVORY & MOORE is the BEST PREPARATION, all the crude products contained therein being made, by scientific manipulation, more susceptible of the transformation necessary for their easy assimilation, while other valuable nutritive ingredients are added, which give it a closer resemblance to the natural food, and so make it far superior in promoting the healthful growth of children. THIS RESEMBLES MOTHER'S MILK AS CLOSELY AS POSSIBLE."

SAVORY & MOORE,
Chemists to the Queen, H.R.H. the Prince of Wales,
H.H. the Khedive of Egypt, &c.,
143, NEW BOND STREET, LONDON,
AND 86, KING'S ROAD, BRIGHTON,
Sold in Tins, 1/-, 2/-, 5/-, and 10/- each.

THE NEW FOOD.

FARINA VITÆ.

Patented in Great Britain, the United States, France, and Belgium.

Pronounced by the Faculty and the Medical Press—

'UNQUESTIONABLY THE BEST DIET FOR CHILDREN & INVALIDS.'

The peculiarity of Farina Vitæ consists in the near assimilation of the elements and principles of certain flours and meals, in such proportions as will render the mixture chemically identical with the constituents of the human body itself. It is therefore obvious that the use of Farina Vitæ will effect a vast economy of the vital forces of the body. It is very agreeable to the palate, and can be prepared in many delicious forms for the table.

It relieves indigestion, constipation, and disorders of the stomach, and maintains the body in sound health. More nutritious than meat; exceptionally rich in phosphates; most excellent for puddings, custards, omelettes, soups, &c.

SOLD EVERYWHERE. 1 lb. Packets, 1s. 6d.

Manufactured by

EDWARDS, ALLEN, & KITCHING

Holland Street, Blackfriars, London.

DR. A. H. HASSALL'S FOOD

FOR INFANTS, CHILDREN, & INVALIDS.

THE BEST FOOD FOR INFANTS AND INVALIDS.

DR. ARTHUR HILL HASSALL, M.D., recommends this as the best and most nourishing of all Infants' and Invalids' Food which has hitherto been brought before the public. It contains every requisite for the full and healthy support and development of the human body, and is, to a considerable extent, self-digestive.

MEDICAL TESTIMONY.

Extract from the *Lancet*, February 20, 1875. 'One of the best Foods that has yet been devised.'

Extract from the *Medical Times and Gazette*, April 10, 1875.—'Like the two most perfect types of Food, Milk and Bread, this Food contains all the necessary elements for sustenance and growth.'

Extract from C. Estcourt, Public Food Analyst for Manchester. — 'Invaluable Food for Infants, or persons of delicate digestive power.'

Extract from Alfred Hill, M.D., Medical Officer of Health, Birmingham.—'A nutritious, readily digestible, and very agreeable Food, adapted for Infants, Children, and Invalids.'

Extract from W. Trench, M.D., Medical Officer of Health, Liverpool.—'Your Food is a valuable addition to the dietetics of the sick room.'

Extract from I. Campbell Brown, M.D., Public Food Analyst for Liverpool.—'Far more desirable as a Food for young Children than the numerous starchy foods which are so much in use.'

Extract from *British Medical Journal*.—'It assimilates in its nutritive value closely to milk, the natural Food for Infants.'

From John Horsley, F.C.S., Public Analyst for the county and city of Gloucester. 'Analyst's Laboratory, Police Station, Cheltenham, county of Gloucester, July 31, 1875.—Closely allied to the composition of human milk, I have no doubt it will, *par excellence*, take the first place in the dietary of any household where there are children and invalids.'

From Francis Sutton, F.C.S., Public Analyst for Norwich.—'County Analyst's Office, Norwich, July 31, 1875.—One of the most perfect Foods for infants and weak persons that has ever come under my notice.'

From W. Walton Stoddart, F.C.S. and C., Analytical Chemist, Analyst for the city of Bristol, August 3, 1875.—'A valuable and appropriate Food for Infants and Invalids, on account of its nutritive qualities, and the ease with which it is assimilated.'

From Edward Moore, Public Analyst for Brighton, August 7, 1875.—'From practical experience of the Food, its careful constitution fits it for just those cases where, as in infants prematurely weaned, an artificial aliment is unavoidable.'

From Henry Johnson, M.D., Shrewsbury, August 7, 1875.—'A great boon to the nursery and sick room. Easy of digestion, very sustaining as well as palatable.'

Sold by Druggists, Grocers, Oilmen, &c., in Tins, 6d., 1s., 2s., 3s. 6d., 6s., 15s., and 28s. each.

A short Treatise by Dr. ARTHUR HILL HASSALL, M.D., on the 'Alimentation of Infants, Children, and Invalids,' can be had for distribution free, on application to the

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LEEDS.

CAN BE USED WITH OR WITHOUT MILK

Dr. Ridge's PATENT COOKED Food

FOR INFANTS, INVALIDS, &c

In a letter to the TIMES, April 1, 1875, W. DOMETT STONE, Esq. M.D., referring to the two deaths of children at Taunton, says:—'Death in both instances clearly resulted from partaking of this preparation'—viz. Corn Flour—and says, 'It cannot be too widely known that Corn Flour, *per se*, is not food, but Pure Starch, prepared by *washing out* the nutritive portion of maize flour.' He further warns people to be on their guard as to these 'foods,' and adjures them to refuse all white preparations, as in these nutriment has been sacrificed for the sake of appearance.

Dr. BARTLETT, the celebrated Analyst, writes to Dr. RIDGE & Co.:—'Your Food proves perfectly genuine; while, for infants and invalids, the lightness must be a most valuable quality.'

Dr. HASSALL, after a full analysis, says:—'These results show that this Food contains constituents belonging to each of the four classes into which foods have been divided, viz. amylaceous, oleaginous, nitrogenous, and mineral. It is therefore a very nutritious article of diet, well adapted for the use of infants, children, and invalids.'

SOLD BY ALL CHEMISTS.

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PICKLES, SAUCES, AND CONDIMENTS.

E. LAZENBY & SON, sole proprietors of the celebrated Receipts and manufacturers of the Pickles, Sauces, and Condiments so long and favourably distinguished by their name, beg to remind the public that every article prepared by them is guaranteed as entirely unadulterated.

92 WIGMORE STREET, CAVENDISH SQUARE
(LATE 6 EDWARDS STREET, PORTMAN SQUARE);
AND
18 TRINITY STREET, LONDON, S.E.

HARVEY'S SAUCE.

CAUTION.—The admirers of this celebrated Sauce are particularly requested to observe that each bottle prepared by E. LAZENBY & SON bears the label, used so many years, signed 'ELIZABETH LAZENBY.'

COLMAN'S

BRITISH

CORN-FLOUR

(PREPARED FROM RICE.)

Is especially adapted for Blanc-Mange, Custards, Puddings, Cakes, Soups, &c., and is a most wholesome food and easily digested by Children and Invalids when prepared with milk.

Extract from the Report of the Committee presented to the House of Commons on 3rd July, 1874;—

The attention of your Committee has been called to the Article known as Corn-flour, in reference to which important evidence as to its purity and its useful dietetic qualities has been given by some eminent and chemical authorities, which, however, is denied by one witness. Your Committee are fully convinced that the manufacture is quite legitimate, and that like Arrowroot, Sago, and other starch foods, Corn-flour is perfectly wholesome, but that it should not in any case be given to infants without a considerable admixture of milk.

MUSTARD AND CORN-FLOUR MANUFACTURERS,

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BEST CORN FLOUR
IS
ANDREW ERKENBRECHER'S

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(THE HIGHEST PREMIUMS),
AT VIENNA, 1873,

For Process of Manufacture and Quality of Goods **AGAINST 149 COMPETITORS** from all parts of the world, after a thorough and searching test by a Jury of skilled Experts in Chemistry.

Highest Awards at CINCINNATI INDUSTRIAL EXPOSITION, 1870 and 1871.

FIRST GOLD MEDAL, BREMEN, 1874.

Vide 'THE GROCER,' *July* 3, 1875.

'As the cost of this corn flour brings it within the reach of all classes, and as it is an article of undeniably good quality, we have little doubt that it will become popular in this country.'

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TWO GOLD MEDALS.

THREE ROYAL WARRANTS.

ACADÉMIE NATIONALE.

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Never be without

KEEN'S MUSTARD.

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TRADE MARK.

The Manufacturers publicly guarantee that all Canisters covered with their well-known Red and Yellow Labels contain nothing but the pure Flour of Mustard, of a quality calculated to maintain the reputation acquired by their firm during the past 130 years.

KINGSFORD'S

OSWEGO PREPARED CORN,

FOR PUDDINGS, CUSTARDS, BLANC MANGE, ETC.

The Original and Best of all Similar Preparations.

Dr. HASSALL reports—'THE OSWEGO PREPARED CORN has been known to me for many years; it is very pure, and may be regarded chemically and dietetically as an arrowroot; taken in conjunction with Milk or Beef Tea it constitutes a valuable article of diet for Infants and Young Children.'

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THE AYLESBURY DAIRY COMPANY are now supplying Milk to a large number of private families.

Their carts visit all parts of the W., S.W., and N.W. districts two and three times daily.

By arrangements lately completed, they are in a position to supply an increased number of customers with pure Milk from carefully-selected farms, and from their own cows in London.

The Directors, having regard to the alarming disclosures made during the last few years with respect to the conveyance of disease by means of milk, have initiated a system of inspection, examination, and analysis by skilled and responsible persons, to which they desire to call attention, and by which they feel that the Company is in a position to give every possible assurance of safety to their customers.

The names of the Gentlemen forming the Directory and Medical Boards, with their Sanitary Inspector, Mr. Ernest Hart, are a sufficient guarantee that the efficiency of the working of the Company is thoroughly attended to.

All orders to be addressed to

Mr. HENRY WHELAN,
Secretary.

THE DAIRY REFORM CO.
LIMITED.

MILK, CREAM,
BUTTER,
EGGS.

29
Orchard Street,
Portman Square.

151 & 153
Ebury Street,
BELGRAVIA.

The Foot and Mouth Disease appears now to have become an annual visitation, and, in the absence of any Government control, there is a risk of some milk from the diseased cows being sent to London for sale.

The small Dairymen who purchase their supplies from the large wholesale dealers have no knowledge whatever of the Farms on which their milk is produced, and consequently, however excellent their intentions, have no security as to its absolute freedom from taint. Immunity can only be secured by such an Establishment as The Dairy Reform Company, whose extensive business and high organisation embraces a complete system of professional inspection.

In addition to this, the Farms supplying them are carefully inspected by the Directors personally, who are experienced and practical men, exercising a daily control over the business, and not, as in some other Companies, gentlemen of well-known names living in London, whose extensive professional engagements preclude the possibility of any real supervision.

The Dairy Reform Company was the first to organise a complete system of Sanitary Inspection of their Farms, and they are now carefully watched by professional gentlemen residing on the spot, and thus *absolute safety is secured.*

Besides their usual deliveries of Milk and Cream, The Dairy Reform Company have lately made arrangements to supply their Customers with the very best Fresh Butter and New Laid Eggs.

For particulars, apply at either of the Company's Branches.

The Farm Inspection Certificates are open for the examination of Customers, at 29 Orchard Street.

29 ORCHARD STREET,
W.

151 & 153 EBURY STREET
S.W.

ESTAB^{D}
1867.

CHIEF OFFICE:—
29 Orchard Street,
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NORWEGIAN CONDENSED MILK.

BEAR Trade Mark Trade Mark BRAND.

CONDENSED from the purest Milk of Cows fed on the natural pastures of the healthful mountain ranges of Norway, where disease is unknown, and the milk produced is peculiarly rich and wholesome. Being prepared by the newest and best process and perfectly genuine, its flavour is more like cream than milk, and for delicate children and invalids will be found most valuable. For the table it is not to be surpassed.

THE GROCER, May 22, 1875, says:—

NORWEGIAN CONDENSED MILK.—This is a new article which has just been brought before the notice of the trade. As the name denotes, this milk is condensed in Norway where the industry is entirely new. It is prepared, according to Borden's process, by the Norwegian Condensed Milk Company, who, in order to insure that their article shall be of the first quality, have engaged a gentleman for many years employed as condenser in Borden's establishment. The **FLAVOUR** of this new condensed Milk, which is sold under the title of the 'Bear Brand,' is all that could be desired, and, with regard to its perfect purity, the testimonials of 'eminent analysts' may surely be accepted upon that point. It may be noticed, also, that the article is prepared from the **PUREST MILK OF COWS** which are fed on natural pastures, and it will readily be imagined that the flavour of the condensed milk procured from such sources is superior to that obtained from cows fed on artificial pastures &c. Having regard to the excellent quality of this condensed milk, and the increasing demand which appears to exist for such an article, we have no doubt that the 'Bear Brand' will become very popular.

PREPARED IN HEDEMARKEN, NORWAY.

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TO FARMERS, CHEESEFACTORS, AND DAIRYMEN

Who wish their CHEESE to have a Prime Colour, and meet a Ready Sale in the London and other Great Markets.

TRADE MARK.

R. J. FULLWOOD & CO.

ORIGINAL INVENTORS OF THE

CELEBRATED FLUID EXTRACT
OF

ANNATTO.

The superiority of this truly excellent, pure, and unadulterated Annatto consists in its producing in Cheese and Butter that rich, permanent **bright golden cowslip tint** so much desired by all Cheese and Butter Factors, and so universally approved in the London and other great markets.

Messrs. R. J. Fullwood & Co.'s Fluid Extract of Annatto now stands **unrivalled and triumphant all over the world.** It is purely vegetable, can always be relied upon, uniform in strength and quality, and cheaper than any other article. The great celebrity of, and increasing demand for, Fullwood's make has led to spurious imitations. To protect the consumers from fraud Messrs. R. J. Fullwood & Co., after using the 'Cow' stamp for 80 years, now stamp all their preparations with their new Trade Mark as above—'A Stag with Olive Branch'—to counterfeit which is felony.

To be had only Genuine from the Annatto Works of

R. J. FULLWOOD & CO.,

24 SOMERSET PLACE, BEVENDEN STREET, HOXTON, LONDON.

ESTABLISHED 1785.

BOTTLES FULL IMPERIAL MEASURE.

Sold throughout England and the Colonies by Chemists, Druggists, and Grocers; but see you get R. J. FULLWOOD'S, *with* 'STAG' *Trade Mark.*

MESSRS. HILL & SON,

BAKERS BY APPOINTMENT TO THE QUEEN

(*Dated April* 19*th*, 1842),

60 BISHOPSGATE STREET WITHIN,
AND
3 ALBERT MANSIONS, VICTORIA STREET, S.W.,

Beg to solicit a trial of their

'HART'S WHOLE MEAL UNFERMENTED BREAD AND BISCUITS.'

This Bread, which is made from the finest Whole or undressed Meal, contains, in perfect purity, the whole constituents of the grain; the phosphates and other inorganic salts so necessary for the proper growth and formation of the bones and teeth, and which are generally resident in the husk, not being removed. For children, and for persons who, from leading a sedentary life, suffer from dyspepsia, it is invaluable.

REPORT FROM DR. HASSALL.

'THE ANALYTICAL SANITARY INSTITUTION, 2 ADELPHI TERRACE, W.C.,
LONDON : 7*th November*, 1870.

'I have made a full and careful analysis of a sample of "THE WHOLE MEAL UNFERMENTED BREAD," as manufactured by Messrs. HILL & SON.

'It possesses several advantages over ordinary white bread.

'In addition to its more agreeable flavour, and greater keeping properties, these advantages are—

- 'That it contains a larger proportion of Nitrogen, and is hence more nourishing.
- 'That the quantity of oily or fatty matter present is greater.
- 'That it contains the peculiar, natural, fermentive, or digestive principle termed "Cerealin."
- 'That it is richer in phosphates.
- 'That it is not so prone to generate acid products as is ordinary bread made with yeast.

'For the above reasons this Bread is to be regarded as a highly valuable article of diet, suited alike for the healthy and the sick, but especially for the young and the dyspeptic.

'ARTHUR HILL HASSALL, M.D.'
Author of 'Food and its Adulterations,' 'Adulterations Detected,' &c.

WHOLE MEAL FLOUR, 10*d.* PER QUARTERN.
WHOLE MEAL GRITS FOR MAKING PORRIDGE, 10*d.* PER QUARTERN.
WHOLE MEAL SCONES, strongly Recommended by many Medical Men.
(The Whole Meal Scones being soft and easily masticated, are admirably adapted for use by elderly people.)

For convenience of persons residing in the Country, HILL & SON *will forward Whol Meal or Grits, with Instructions for manufacturing either Bread or Porridge.*

List of Whole Meal Biscuits forwarded on application.

POOLEY'S PATENT

MALT BREAD.

IT may be stated as an axiom, that other things being equal, the measure of a man's strength will be in proportion to the amount of nutritive food he can take and assimilate.

Bread being universally consumed, in larger quantity than any other food, it is of the utmost importance that it should contain the largest amount of nutriment in the most readily assimilative form.

It is well known that Invalids, and those whose digestion has become impaired, cannot take sufficient ordinary Baker's Bread to supply the need of nourishment to the wasted body; hence the rise of so many attempts to supply concentrated nourishment in such cases, with but very imperfect results.

By the addition of Malt to Wheat-Flour, in the process of making, it has been found that the resulting Bread is much more readily digested, the stomach being saved a portion of the preliminary process of preparing it for assimilation.

The advantage of this, in so many cases familiar to the Medical Practitioner, will be self-evident; and it is confidently anticipated that the **Patent Malt Bread** will speedily become the standard Bread for persons with feeble powers of digestion.

DR. HASSALL'S REPORT

On a Sample of PATENT MALT BREAD received from Mr. JOHN C. POOLEY.

'This bread is of a sweet and very pleasant odour and taste, and possesses a malt-like flavour. Subjected to analysis it was found that it contained less than the usual percentage of moisture, that it was free from alum, and in all other respects genuine and of good quality.

'The flavour and other peculiar characteristics of this bread are no doubt due to the presence of the malt-flour, the diastase contained in which, promotes greatly the conversion of the starch into sugar, and thus renders the subsequent digestion more easy and rapid.

'ARTHUR HILL HASSALL, M.D.

'14 John Street, Adelphi, *June* 12*th*, 1875.'

POOLEY'S PATENT MALT BREAD

Is not only more readily digested, but is more nutritious, more agreeable to the palate, and will keep sweet and moist much longer than ordinary Bread.

Licenses granted to Bakers, on easy terms, in Districts not yet occupied.

JOHN C. POOLEY, Chemist, Bath, Patentee.

HICKS'S BAKING POWDER.

HICKS'S
BAKING POWDER.
PUDDINGS WITHOUT EGGS.
PASTRY WITH LESS BUTTER.
SUPERIOR TO YEAST.
FOR MAKING BREAD, AND CAKES.
LIGHT, WHOLESOME, & DIGESTIBLE.

FACSIMILE OF LABEL.

The above Baking Powder, having acquired in a very short period a large sale, now holds a leading position among the various compounds of its kind. This has resulted solely from the actual merits of the preparation. In its manufacture no materials but the very finest and purest are used, and their proportions are so accurately arranged that Bread or Cakes made with this Powder are perfectly sweet and palatable, having no trace of bitterness, which often arises from the use of some Baking Powders, as it also frequently does when Brewer's Yeast is employed.

Hicks's Baking Powder can therefore be highly recommended for all kinds of Bread, Cake, Puddings, or Pastry; and the subjoined extract from Dr. Hassall's analytical report, is satisfactory evidence of its wholesomeness, and superiority over many other Baking Powders.

(*Extract from Report.*)

'Of the many Baking Powders Hicks's Powder appears to me to be one of the most suitable. It is composed of perfectly harmless ingredients, and is FREE FROM ALUM, so frequently introduced into bread for the purpose of rendering it white, which substance is present in many Baking Powders.'

ARTHUR H. HASSALL, M.D.
Author of 'Food and its Adulterations,' 'Adulterations Detected,' late Editor of 'Food, Water, and Air.'

Sold by Grocers, Druggists, and Corn Chandlers, in 1d. and 2d. packets, and 6d. and 1s. Patent Boxes.

WHOLESALE OF THE MANUFACTURERS,

HICKS, BROTHERS,
1 MAIDEN LANE, QUEEN STREET,
LONDON E.C.

FREEMAN'S

DIGESTIVE BAKING POWDER

AND

DIGESTIVE EGG POWDER.

LARGEST PENNY PACKETS.

BEST QUALITY EVER SOLD.

TRADE **TRY IT.** MARK.

Dr. BRETON, Ph.D., says :—'I find your Digestive Baking Powder is what an article of Domestic economy ought to be—FREE FROM ALUM OR ANY INJURIOUS INGREDIENT. I have also been enabled to observe the excellent quality of each article used in the manufacture. A Baking Powder thus prepared needs no comment.'

Signed—WALTER BRETON, Ph. D.,
Author of 'Report on Drinking Waters on South Coast' &c. &c.

Dr. BRETON, Ph.D., says :—'Freeman's Digestive Egg Powder will be found to lessen the labour in making Puddings &c., as with the use of this Powder it can be mixed and laid aside until convenient to be cooked. I find also the ABSENCE OF ALUM OR ANY INJURIOUS INGREDIENT. This Powder can therefore be added to the list of digestible articles of diet.'

Signed—WALTER BRETON, Ph.D.,
Public Analyst,
Author of 'Reports on Drinking Waters' &c.

These articles, on *merit* alone, have had an enormous sale during the past seven years, and their *continually increasing sale* is the best proof of their superior qualities.

We will not, however, make much comment, but respectfully refer you to the Trade Mark—**TRY IT.**

JUDGE FOR YOURSELVES—A PENNY PACKET CAN BE THE TEST.

Sold by Corn Dealers, Grocers, Oilmen, &c., Everywhere.

MANUFACTURERS—

FREEMAN & HILDYARD,

DOVER ROAD, BOROUGH, LONDON, S.E.

COLMAN'S
GENUINE
MUSTARD

Is the PURE FLOUR of the FINEST MUSTARD SEED.
and can be obtained of all Grocers and Oilmen.

TRADE MARK. BULL'S HEAD.

J. & J. COLMAN'S

(Other Qualities are admixtures and are so notified on each package.

J. & J. COLMAN beg to call special attention to the fact that their Genuine Mustard is always labelled "WARRANTED PURE," while all their qualities of MIXED MUSTARD bear the printed notice—"This preparation is an admixture of Pure Mustard with Farina and Choice Condiments."–*(Sale of Food & Drugs Act,* 38 & 39 *Vict., ch.*63.*)*

Mustard and Corn-flour Manufacturers.

108 Cannon Street, London.

SMITHDALE'S

Unrivalled for Purity
and
Excellence.

GENUINE

Ask
your Grocer
for it.

NORWICH

MUSTARD

IS THE BEST.

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48 ST. JAMES STREET, S.W.
City Branch—122 CANNON STREET,
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JOHN GARDINER, Esq.
CHAS. W. REYNOLDS, Esq.
Sir J. E. EARDLEY WILMOT, Bart., M.P.

The last Report, copies of which, with the statements of accounts, can be obtained on application, shows that a sum equal to 40 per cent. of the premium income was added to the funds, while the general income was increased.

349 Policies, averaging £535 each, were issued.

The Directors continue to make advances to assurers in the office on liberal terms.

H. D. DAVENPORT, *Secretary.*

GLENFIELD.

THE
QUEEN'S
LAUNDRESS
SAYS THIS STARCH
IS THE BEST
SHE EVER
USED.

GLENFIELD.

RICHMOND & CLARKE,

FROME.

PURE MALT VINEGAR

(Made entirely from Grain)

In CASKS of 12½, 25, 30, 50, and 60 Gallons.

Delivered free to any Railway Station within
120 miles of Frome.

Casks allowed for as charged, if returned in good condition.

PRICE LISTS ON APPLICATION AS ABOVE.

EIGHT GOLD MEDALS AND GRAND DIPLOMAS OF HONOUR
For BEST QUALITY, and as
FOUNDERS of a NEW BRANCH of INDUSTRY.

LIEBIG COMPANY'S EXTRACT OF MEAT.

Manufactured by Liebig's Extract of Meat Company, Limited.

No. 43 MARK LANE, LONDON,

AT THEIR MANUFACTORIES IN SOUTH AMERICA.

TRADE MARK

THIS Extract is supplied to the British, German, French, Russian, Dutch, Italian, and other Governments, in preference to all other Extracts.

One Pound of the Extract contains the soluble parts of 34 lbs. of Fine Beef, free from fat and gelatine.

It is not only used for medical, but much more extensively used for household purposes and is the cheapest and finest flavoured stock for soups, entrées, sauces, &c.

DECLARATION.

We the undersigned, hereby declare that LIEBIG COMPANY'S EXTRACT OF MEAT, from FRAY-BENTOS, as hitherto, must be examined and approved by us, before it can be delivered to consumers; and that consequently, The Extract, prepared strictly according to the instructions of the inventor, will also in future always be of the same acknowledged uniform excellence and perfection as hitherto.

Munich, May 1873.

Hv Liebig
DELEGATE.

CAUTION.

Every genuine Jar bears on the Certificate Label round the Capsule, the above-mentioned two Signatures of PROFESSOR DR. MAX VON PETTENKOFER and BARON HERMANN VON LIEBIG, and across the Trade Mark Label the fac-simile of the inventor, BARON JUSTUS v. LIEBIG, in blue.

Sold by all Grocers, Italian Warehousemen, Chemists, Provision Merchants, and Ship Chandlers.

GEYELIN'S
CONCENTRATED FOOD
FOR THE MILLION.

10 PRIZES. **10 PRIZES.**

SOUPS.
(Julienne.)

These Soups are used all the year round, and are, in fact, a *necessary* to improved and economic cookery, as evidenced by the adoption by all the principal cooks in this and other countries.

TRADE MARK.

MILK FOOD,

Which is manufactured on the same principle as their celebrated Beef Gravies, in a dry Powder, will keep for years, and is highly esteemed for Breakfast, or Infants' and Invalids' Diet.

Can be obtained through all Chemists and Grocers, or at their Warehouse, in Canisters, or 2*d.* Packets, at the following prices :—

SOUPS.		IN CANISTERS	MILK FOOD.
Tapioca Beef Bouillon ..	Plain or Season'd	of 5 pints 1/- each	Tapioca and Cream Powder.
Arrowroot Beef Bouillon		12 ,, 2/3 ,,	
Revalenta.............		25 ,, 4/6 ,,	Chocolate Cream Powder.
Pea Soup		*50 ,, 8/6 ,,	Coffee and Cream Powder.
Mulligatawny Soup		100 ,, 16/- ,,	

* Size recommended for Family use; each Canister contains a measure for one pint of Food.

The above Soups and Milk Food may now also be obtained in

TWOPENNY PACKETS,

Each making a Pint of substantial and nutritious Food.

The Soups are used also for Enriching, Thickening, and Colouring Gravies, Stews, Hashes, Minces, Meat Puddings, Pies, &c.

Packets in Paper Boxes of Quarter-Gross .. .. .. 6*s.*
And in Wood Boxes of One Gross Packets .. .. .. 24*s.*

Sample Boxes, containing Six Packets of different Soups and Milk Food, 1s. 6d. post free.

GEYELIN & CO., Concentrated Food Manufacturers,

LONDON : BELGRAVE HOUSE, ARGYLE SQUARE, W.C.

WILLIAM BAILEY & SON,

BY APPOINTMENT,

Manufacturers of Chemicals for Telegraphic, Photographic, Pyrotechnic, and other purposes. Contractors to Her Majesty's War Office, Admiralty, Post Office, India Office, and other Government Departments. Also to the principal Railway and Telegraph Companies in Great Britain.

Great attention is given to the Manufacture of Chemicals and other Preparations for Commercial and Scientific Use.

Works—HORSLEY FIELDS, WOLVERHAMPTON.
London Offices—2 & 3 ABCHURCH YARD, CANNON ST., E.C.

The following Specialities are particularly recommended.

BAILEY'S TANNATE OF SODA, for preventing Incrustations in Steam Boilers, and removing the Scale already formed therein, a considerable saving of fuel being also effected. PRICE 36*s.* PER CWT.

BAILEY'S CLEANSING POWDER possesses very remarkable detergent properties, and when mixed with either fresh or sea water, cleanses every variety of Wood or Metal to which it may be applied. PRICE 28*s.* PER CWT.

BAILEY'S SANITARY FLUID is specially adapted for Purifying the Atmosphere in Factories, Workshops, Hospitals, and Public Institutions, and for disinfecting purposes generally. PRICE 1*s.* 6*d.* PER GALLON.

DINNEFORD'S FLUID MAGNESIA.

For Thirty Years the Medical Profession have approved of this pure Solution as the best remedy for

ACIDITY OF THE STOMACH, HEARTBURN, HEADACHE, GOUT, & INDIGESTION,

And as a mild Aperient for delicate Constitutions, especially adapted for Ladies, Children, and Infants. When combined with

THE ACIDULATED LEMON SYRUP,

It forms a most agreeable effervescing draught, in which its aperient and cooling qualities are much increased. In warm seasons and warm climates, this simple preparation, when taken REGULARLY, has been found highly beneficial.

DINNEFORD & CO., Chemists &c., 172 New Bond Street, London.

Sold by all respectable Chemists throughout the World.

CAUTION.—See that 'DINNEFORD & CO.' is on each Bottle, and Red Label over the Cork.

Extract from Analytical Report by **WENTWORTH L. SCOTT**, Esq., F.C.S. &c.:—'The simplest, safest, and most effective means for the "preservation of animal substances."'

MEDLOCK & BAILEY'S PATENT BISULPHITE OF LIME,

For the Preservation of Meat, Fish, Poultry, Game, and all other Animal Substances,

IN TEMPERATE OR TROPICAL CLIMATES, AND ON BOARD SHIP.

BY the use of this valuable Preparation, Fresh Meat can be had throughout a voyage, however long, thus avoiding the expenses and losses incidental to the conveyance of live stock on board. No steamer or passenger ship should be without it, as it will enable captains to lay in provisions at foreign ports, wherever they are cheap and good, relieving them of the necessity of providing for the voyage home. It imparts no flavour to the meat, nor does it lessen its nutritive value, while it prevents scurvy and destroys contagion wherever it is used. For further particulars see Descriptive Pamphlet, and also opinions of the press, both sent post free for seven stamps.

Extract from the 'Times' Money Article of December 10, 1870.

'There was a trial of Preserved Meat from Rosario, in the Argentine Republic, in the City on Wednesday, with, it is stated, most satisfactory results. The preparation was effected by immersion in a solution of Bisulphite of Lime, according to the process of Messrs. Medlock & Bailey, of the Horseley Fields Chemical Works, Wolverhampton, and the meat was sealed up in a cask in the presence of Mr. Hutchinson, the British Consul at Rosario, on the 10th of August last, and brought by him to this country in a recent steamer. It had, therefore, been kept four months, and had made a passage across the Line, yet was found perfectly fresh, not only in quality, but in appearance, and was deemed by the persons present at the trial equal to any good ordinary home beef. Amongst these persons were merchants largely interested in the commerce of the River Plate, by whom an unqualified conviction has since been expressed that the problem of bringing unlimited supplies of animal food from distant regions will now prove to have been solved, the method being alike simple and inexpensive, and capable of been adopted under any circumstances. At the trial on Wednesday not the slightest flavour of any chemical or other artificial agent was detected.'

The meat was cooked at SIMPSON'S, Bolt Court, Cornhill, and was partaken of by a number of influential gentlemen and merchants interested in the question, including M. B. Simpson, Esq., Consul-General of the Argentine Republic; Consul-General Neil, of Uruguay (copies of whose Official Certificates can be had on application), &c.

Extracts from a few of the communications lately received by the Patentees.

SIR JAMES MATHESON, BART., M.P., *enclosing a further order*:—'Sir James Matheson is glad to tell Messrs. William Bailey & Son that their Bisulphite of Lime answered perfectly in carrying the carcases of a deer and a calf from Stornaway to London, *quite fresh*, being on the journey and voyage four days, during the very hot days of June; besides enabling the venison and veal to be kept twelve days after arrival by using the Bisulphite according to directions.'

THOMAS J. HUTCHINSON, ESQ., F.R.G.S., F.A.S.L., *Her Britannic Majesty's Consul for Rosario, Rio de la Plata*:—'When at Monte Video, I had the pleasure of tasting at breakfast a small piece of beef prepared by the Bisulphite of Lime, sent out to the Plate. It was given to me by Mr. Prange. The preservation of that meat was perfect, and it was the first piece of real juicy beef that I have tasted for the last seven years.'

DR. STONE, *Health Officer, Trinidad*:—'I have found your Bisulphite of Lime of great value as a means of preserving meat.'

THOMAS SUTTON, ESQ., B.A., *of Redon, France*:—'At last I have tried your Bisulphite of Lime, and I find it a great success. We dined yesterday off a leg of mutton which I had preserved, and found it delicious—undistinguishable from fresh meat—no flavour of the Preservative—rich red gravy—no loss of weight. Every word is true that you say in your Pamphlet.'

THE GOVERNOR OF THE CITY POOR HOUSE, *Edinburgh*, 'is highly pleased with the results obtained from the use of your Bisulphite.'

MR. J. W. SALISBURY, *Meat Salesman, of Newgate Market, London*:—'It is a *most valuable thing* for butchers.'

MR. GEORGE BLACKMAN, *Butcher, of Newport Market, London*:—'I find Medlock and Bailey's Patent Preserving Liquid invaluable.'

MR. GEORGE SEARLETT, *Butcher, of Notting Hill, London*:—'I believe there is nothing to be compared with your Bisulphite.'

MR. ALEXANDER M'ALLISTER, *Fish and Game Salesman, of Glasgow*:—'By your Patent Process I have succeeded quite beyond my most sanguine expectations.'

MESSRS. HOPER & SCHWERIN, *of Berlin, September* 17, 1869:—'We have much pleasure in informing you to-day that our success with meat as well as beer has been complete beyond expectation.'

In addition to its remarkable powers in preserving animal substances from decay, MEDLOCK & BAILEY'S Bisulphite of Lime is also an absolute specific against epidemic Cattle Disease, if used in accordance with the Patentee's instructions. It thus enables the Shipper to carry either 'live or dead' meat in perfection, without fear of loss in transit from the bad health of the one, or the decomposition of the other.

Sole Manufacturers—Messrs. WILLIAM BAILEY & SON, *Horseley Fields Chemical Works, Wolverhampton;*

And 2 and 3 Abchurch Yard, Cannon Street, London, E.C.

e GENUINE Bisulphite of Lime of MEDLOCK & BAILEY ONLY should be used. Price, 3*s.* 6*d.* per gallon, packages included.

HOOPER'S

Brighton Seltzer

Per 4/- Doz.

OF THE PRINCIPAL CHEMISTS & WINE MERCHANTS.

Wholesale & Export of the Manufacturers,
HOOPER & COMP$^{Y.}$, 7, *Pall Mall East, London.*

SANITARY WATER SUPPLY

For Town and Country Residences, Large Buildings, Villages, &c.

MESSRS. ATKINS & CO.

Invite attention to their new Improved System, recently patented. The most perfect method of insuring abundance of pure water yet introduced.

Advice, Drawings, and Estimates for Filtration of Water upon any scale and for any purpose.

PROSPECTUS FREE.

☞ *The Only System in use at the Royai College of Surgeons, Royal Navy, Lighthouses, Indian Army, State Railways, &c.*

HOUSEHOLD FILTERS FROM 6s.

ATKINS & CO.

HYDRAULIC & SANITARY ENGINEERS,

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TOWNSON & MERCER,

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LONDON,

WHOLESALE AND EXPORT DEALERS

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CHEMICAL AND SCIENTIFIC APPARATUS.

Manufacturers and Importers of Pure Chemicals and Graduated Instruments for Analysis and the Laboratory Use of Manufacturers, Mines, Universities, Colleges, Medical Officers of Health, &c.

Manufacturers of Electrical, Galvanic, and Philosophical Instruments.

ILLUSTRATED CATALOGUES, PRICE 3*d.*

The Instruments and Apparatus used in Dr. HASSALL'S Laboratories are obtained, for the most part, from Messrs. TOWNSON & MERCER.

PRIZE MEDAL
TOILET SOAPS & PERFUMERY.

YARDLEY & CO.,
ESTABLISHED UPWARDS OF 100 YEARS,
**FANCY SOAP MAKERS
AND PERFUMERS,**
7 VINE ST., BLOOMSBURY, LONDON, W.C.
And 5 RUE DU GRAND CHANTIER, PARIS,
MANUFACTURE HIGH-CLASS SOAPS ONLY,

And respectfully direct the attention of the Public to the following Specialities, which have for many years borne the highest reputation for exquisite fragrance, healthy action on the skin, and improvement to the complexion:—

Choice Old Brown Windsor
Musk Scented Windsor
Pure Glycerine Soap
White Glycerine Soap
Patent Sunflower Oil Soap
Elder Flower Soap
Turtle Oil Soap

Oatmeal Soap
Otto of Rose Soap
Genuine Honey Soap
Cold Cream Soap
Medicinal Carbolic Acid Soap
” Stockholm Tar Soap
” Sulphur Soap
” Kaolin and Myxodine, especially adapted for Children and Ladies' use.

ALSO EVERY DESCRIPTION OF
ESSENCES, LAVENDER WATER,
WASHES AND POMADES FOR THE HAIR.
CHERRY TOOTH PASTE, VIOLET POWDER, &c. &c.

JUST COMMENCED,

In **Monthly Parts,** price **7d.** and **8½d.**

CASSELL'S

DICTIONARY of COOKERY.

Illustrated with **FULL-PAGE COLOURED PLATES** and numerous **ENGRAVINGS,** and containing nearly **Ten Thousand** Receipts in every Department of British, Continental, and American Cookery, being SEVERAL THOUSAND MORE than are contained in any existing work.

'CASSELL'S DICTIONARY OF COOKERY begins excellently well, and when completed should be a TRUE HOUSEHOLD TREASURE.'—*Illustrated London News.*

'Of all the things in the army that go wrong, cooking goes most wrong. We commend CASSELL'S DICTIONARY OF COOKERY to all sergeant-cooks and all sensible officers' wives.'—*Naval and Military Gazette.*

'"Meg Dods." and "Francatelli" are all very well, but for households of all classes commend us to CASSELL'S DICTIONARY OF COOKERY.'

Edinburgh Daily Review.

'Those who study CASSELL'S DICTIONARY OF COOKERY, which contains instructions suited to all classes, and yet are unable to produce appetising, wholesome, and elegant repasts, must be stupid indeed.'—*Northampton Mercury.*

⁎⁎⁎ *Order* **PART I.** *(including Coloured Plate), price* **8½d.**

CASSELL, PETTER, & GALPIN, Ludgate Hill, London.

In **Monthly Parts,** price **7d.** and **8½d.**

CASSELL'S ILLUSTRATED

HISTORY OF INDIA.

⁎⁎⁎ *SPECIAL NOTICE.—With Part I. of* **CASSELL'S ILLUSTRATED HISTORY OF INDIA,** *price* 8½d., *is issued, as a PRESENTATION PLATE, a life-like* PORTRAIT *of* HIS ROYAL HIGHNESS *the* PRINCE OF WALES, *produced in the best form of Art, and uniform, in size, style, and quality, with the valuable Portrait of HER MAJESTY, issued with Part I. of 'Cassell's History of England,' to which it is intended that the Portrait of the Prince shall form a COMPANION PICTURE.*

CASSELL, PETTER, & GALPIN, Ludgate Hill, London
and all Booksellers.

3

BONUS YEAR 1875.

NORTH BRITISH & MERCANTILE
INSURANCE COMPANY.

A Valuation to ascertain the PROFITS on the LIFE ASSURANCE BUSINESS for the Five Years from 1st January 1870 will be completed early in 1876.

All Policies opened on the Participating Scale on or before the 31st December 1875 will be included in the Scheme of Division.

NINE-TENTHS of the WHOLE PROFITS are allocated to the Participating Policyholders.

THE BONUS at the last Declaration ranged, according to the age of the Policy, from **£1. 5s.** to **£1. 19s.** per cent. per annum on the Original Sum Assured, the principle of Division being to declare the Bonus not only on the Original Sum Assured but also on the previous Bonus Additions.

The Accumulated Funds of the Life Department at 31st December 1874 were as follows: —

1. Life Assurance Branch	£2,396,269 11 10
2. Annuities Branch	286,243 15 8

The Revenue from Life Premiums and the Interest on these Funds amounted for 1874 to £409,990 10 2

Irrespective of the Security afforded by these Funds, Policyholders have the general security afforded by

The Subscribed Capital	£2,000,000
The Paid-up Capital	250,000

The Rates of Premium chargeable are moderate both for Home and Foreign Residence.

New and specially advantageous Civil and Military Rates for India, China, &c., have recently been introduced.

Liberal Conditions. Policies indisputable after 5 years.

ANNUITIES of all kinds are granted by the Company, and the rates are fixed on the most favourable terms.

Tables of Rates, and full information, may be obtained at any of the Company's Offices or Agencies in the United Kingdom.

DAVID SMITH,
General Manager.

November 1875.

CHIEF OFFICES { EDINBURGH, 64 PRINCES STREET.
LONDON, 61 THREADNEEDLE STREET.
,, (*West-end Office*) 8 WATERLOO PLACE.

COMPOSITION KNOWN & APPROVED BY THE MEDICAL PROFESSION

TOWLE'S CHLORODYNE

RENOWNED FOR GIVING SPEEDY RELIEF IN

COUGHS, CONSUMPTION,
ASTHMA, BRONCHITIS, DIARRHŒA, CHOLERA, SPASMS,
SEA-SICKNESS,

AND MOST AFFECTIONS OF THE NERVOUS SYSTEM.

THE value of CHLORODYNE depends upon the integrity of its Manufacture; and, to prevent disappointment, it is necessary to Caution the Public to ask for TOWLE'S CHLORODYNE, and see that they get it, as numerous inferior and cheap Preparations are in the market.

The Original and Genuine bears Facsimile of Proprietor's Signature on Government Stamp.

The Proprietor is constantly receiving Letters—a few Extracts only can be published.

From a Gentleman, in ——.—'A woman in my district, 67 years of age, for many years a sufferer from Asthma, has been wonderfully restored by one bottle of your Chlorodyne. When I saw her first she was unable to move about, and had to be carried up-stairs to bed. When I saw her again, after taking your Chlorodyne, she was able to go to market, get up-stairs, and make her own bed—she said, "she believed it had doubled her life."' . . . .

From a Gentleman, at ——.—'I have had my Wife bad with a severe Cough for five years, and have tried Doctors and various Patent Medicines to no use. A Lady friend persuaded us to try your Chlorodyne, and I can assure you you have our warmest thanks for the MAGIC-like effects, completely driving away a five years' old Cough.' . . . .

From London.—'Less than one bottle completely ERADICATED a severe Cold on my Lungs in less than a week.'

From Ashton.—'Myself, Wife, and Child were seriously attacked with Griping Pains and Diarrhœa. I went to the Druggist's and got a bottle of your Chlorodyne, gave each a dose,—the result was perfectly astonishing; after the second dose, it entirely disappeared.' . .

Price 13½d., 2s. 9d., and 4s. 6d., with full Directions.

TOWLE'S CHLORODYNE LOZENGES

Of superior Quality and Strength.

EACH LOZENGE STAMPED 'TOWLE'S CHLORODYNE.'

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